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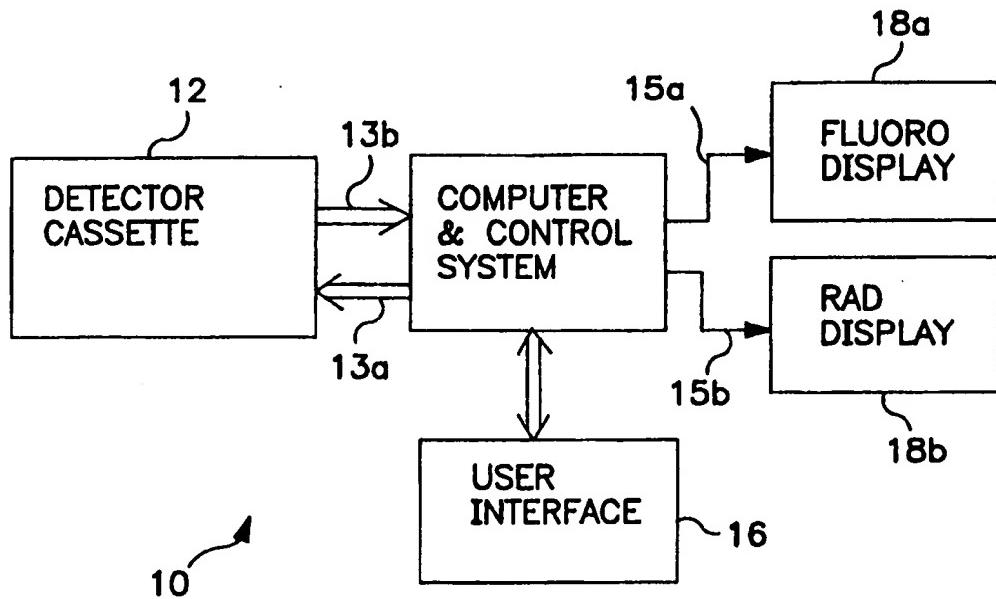
(57) Abstract

A multiple mode digital X–ray imaging system providing for preprocessing "binning" of analog pixel signals from a detector array by selectively summing, within the detector array, adjacent pixel charges on a row–by–row basis and selectively summing, within detector array readout circuits, the previously summed pixel charges (by rows) on a column–by–column basis. An array, or mapping, of "defective pixel" flags is used to identify defective pixels within the detector array, with such flags being added to, or inserted into, the incoming data stream for dynamic processing along with the incoming pixel data. A buffer and filter is used to perform still image capture during the radiographic mode of operation and to recursively filter incoming data frames during the fluoroscopic mode of operation by summing a scaled amount of pixel data from prior data frames with a scaled amount of incoming pixel data from the present data frame.

MULTIPLE MODE DIGITAL X-RAY IMAGING SYSTEM

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/056,926

which was converted to provisional status from U.S. Non-Provisional Application No.

08/753,799, which was filed on November 29, 1996, and entitled "Multiple Mode Digital

X-Ray Imaging System."

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BACKGROUND OF THE INVENTION

The present invention relates to radiation imaging systems, and in particular, to solid

state X-ray radiation imaging systems capable of operating in multiple detection and display

modes.

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DESCRIPTION OF THE RELATED ART

The use of X-ray radiation has become a valuable and widespread tool in medical

diagnoses and treatments. In film radiography, a burst of X-rays, after passing through the

body, is recorded on high resolution X-ray film. In fluoroscopy, an image intensifier tube

15 converts X-ray radiation to a video signal for viewing and recording interior body activity as

a video image.

Film radiography is commonly used due to its good spatial resolution, high signal-to-

noise ratio (SNR), large detection area and low cost. However, developing exposed X-ray

film typically takes a minimum of ninety seconds which can be too long in emergency

20 situations. Further, the relatively low dynamic range of X-ray film can result in under- or

over-exposed images and, therefore, necessitate additional exposures which increase the

aforementioned time delay as well as the X-ray dosage received by the patient.

The image intensifier tube used in fluoroscopy has a greater exposure latitude than

X-ray film, but also has a more limited active detection area and lower spatial resolution.

The lower spatial resolution associated with the total active area is somewhat mitigated in

that the image intensifier tubes allow magnification of the central image portion, thereby

providing a means to enhance visual details. However, the image intensifier tube is typically

5   heavy, bulky and expensive, and can introduce image distortion which can only be partially

removed during post processing.

A number of alternative X-ray imaging technologies have been developed. For

example, one alternative, known as computed radiography, involves the use of a

photostimulable phosphor plate which has the same physical appearance as a standard X-ray

10   film cassette and provides good spatial resolution, SNR and dynamic range. However, after

exposure to X-rays, the photostimulable phosphor plate must be scanned with a laser system

which is large and expensive, and the readout process is just as slow as the development of

film.

Another alternative which provides good spatial resolution and dynamic range, as

15   well as the added advantage of compatibility with real time digital image processing

techniques, involves the use of solid state detector panels. One such panel uses an

amorphous silicon (a-Si) detector array arranged as a two dimensional matrix of pixels, each

of which consists of a photosensitive element and a transistor switch. As with X-ray film

cassettes, the detector array is covered with a scintillation layer to convert impinging X-rays

20   into visible light for the photosensitive elements.

SUMMARY OF THE INVENTION

An X-ray imaging system in accordance with the present invention is capable of operating in multiple imaging modes, such as radiographic and fluoroscopic, while providing spatial resolutions, SNRs and dynamic ranges which can be selectively optimized to the

5   selected mode of operation.

In accordance with one aspect of the present invention, the combining of pixel information collected by the detector array, i.e., "pixel binning," is performed by selectively combining one portion of the pixel information within the detector array and selectively combining the remainder of the pixel information within the circuits fed by the output of the

10   detector array. Such pixel binning is preferably analog in nature and is performed prior to any digitizing of the pixel signals, thereby providing for a higher SNR, and, importantly, reducing the bandwidth requirements for the digital electronics. More specifically, a multiple mode X-ray detector system for supporting multiple X-ray image display modes by providing X-ray image signals having selectable spatial resolutions includes a detector array

15   and a group of detector array receiver circuits. The detector array is configured to receive a group of detector control signals and in accordance therewith receive and convert X-ray photons corresponding to a two-dimensional image into a first group of image signals representing a first two-dimensional array which includes a first group of rows and a first group of columns of pixels which together correspond to the two-dimensional image and

20   which individually correspond to respective portions of the two-dimensional image. The detector array provides, in accordance with the detector control signals, a second group of image signals representing a second two-dimensional array which includes a second group of rows and the first group of columns of super pixels which selectively represent respective

4

individual ones or multiple adjacent ones of the first group of rows of pixels and respective

individual ones of the first group of columns of pixels, respectively. The detector array

receiver circuits, coupled to the detector array, are configured to receive a group of receiver

control signals and in accordance therewith receive and combine the second group of image

5   signals and in accordance therewith provide a third plurality of image signals representing a

third two-dimensional array which includes the second group of rows and a second group of

columns of super pixels which selectively represent respective individual ones of the second

group of rows of super pixels and respective individual ones or multiple adjacent ones of the

first group of columns of super pixels, respectively.

10   In accordance with another aspect of the present invention, data flags are used to

identify defective pixels within the detector array and are inserted into the data stream

collected from the detector array for dynamic processing along with the pixel data. More

specifically, a data processing system for processing a serial stream of multiple bit data sets

which represent an array of pixels corresponding to a two-dimensional image including

15   correcting for defective pixels individually or in groups includes a data processing circuit and

a data selection circuit. The data processing circuit is configured to receive and process

together a plurality of successive sets of image data with a corresponding plurality of

successive sets of correction data and in accordance therewith provide a plurality of

successive sets of corrected image data. The plurality of successive sets of image data

20   represents a plurality of pixels corresponding to a two-dimensional image, the plurality of

successive sets of correction data represents a plurality of correction factors, each one of the

plurality of correction factors corresponds to a respective one of the plurality of pixels and

each one of the plurality of successive sets of correction data includes a data subset which

indicates whether the respective one of the plurality of pixels is defective. The data selection

circuit, coupled to the data processing circuit, is configured to receive and select between

individual ones of the plurality of successive sets of corrected image data and individual ones

of the corresponding plurality of successive sets of correction data and in accordance

5   therewith provide a plurality of successive sets of selected data. An individual one of the

plurality of successive sets of selected data includes a corresponding individual one of the

plurality of successive sets of correction data when the data subset indicates that the

corresponding respective one of the plurality of pixels is defective, and the individual one of

the plurality of successive sets of selected data includes a corresponding one of the plurality

10   of successive sets of corrected image data when the data subset does not indicate that the

corresponding respective one of the plurality of pixels is defective.

        In accordance with still another aspect of the present invention, a data buffer and

filter is used to perform still image capture during radiographic imaging and to recursively

filter incoming image data during fluoroscopic imaging. More specifically, a digital data

15   buffer and filter for selectively storing image pixel data, combining new incoming image

pixel data with previously stored image pixel data and providing such combined image pixel

data for display thereof in a still image mode or an image motion mode includes a data

scaling and summing circuit and a data memory circuit. The data scaling and summing

circuit is configured to receive and scale an input data signal, receive and scale a stored data

20   sum signal and sum said scaled input data signal and said scaled stored data sum signal and

in accordance therewith provide a data sum signal. The input data signal is scaled in

accordance with a first scaling factor and the stored data sum signal is scaled in accordance

with a second scaling factor. The input data signal includes a plurality of successive sets of

image data, and each one of the plurality of successive sets of image data includes a plurality of pixel data with active and inactive data states and which corresponds to a two-dimensional image having a two-dimensional array including a plurality of rows and a plurality of columns of pixels which together correspond to the two-dimensional image and which

5 individually correspond to respective portions of the two-dimensional image. The data memory circuit, coupled to the data scaling and summing circuit, is configured to receive and selectively store the data sum signal and provide the stored data sum signal. The data scaling and summing circuit and the data memory circuit cooperatively operate in one of a plurality of operational modes during reception of the plurality of successive sets of image

10 data. In a first one of the plurality of operational modes (e.g., in fluoroscopic mode), the first scaling factor has a value which is between zero and unity, and the second scaling factor has a value which equals a difference between unity and the first scaling factor value. In a second one of the plurality of operational modes (e.g., in radiographic mode): the first scaling factor has a value which is initially unity when a first one of the plurality of

15 successive sets of image data is in the inactive data state, remains unity when a subsequent second one of the plurality of successive sets of image data is in the active data state and becomes zero when a further subsequent third one of the plurality of successive sets of image data is in the inactive data state; and the second scaling factor has a value which is initially zero, becomes unity when the subsequent second one of the plurality of successive sets of

20 image data is in the active data state and remains unity thereafter.

These and other features and advantages of the present invention will be understood upon consideration of the following detailed description of the invention and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a functional block diagram of an X-ray imaging system in accordance with the present invention.

Figure 2 is an exploded perspective view of an X-ray detector cassette for an X-ray imaging system in accordance with the present invention.

Figure 3 is a schematic diagram of a portion of the detector array of Figure 2.

Figure 4 is a functional block diagram of the array driver circuit assemblies of Figure 2.

Figure 5 is a functional block diagram of the receiver circuit assembly of Figure 2.

Figure 6 is a functional block diagram of the readout circuits in the receiver circuit assembly of Figure 5.

Figure 7 is a simplified schematic diagram of several adjacent preamplifier circuits in the readout circuit of Figure 6.

Figure 8 is a functional block diagram of the portion of the computer and control system of Figure 1 in which the image data is processed for display in accordance with the selected mode of operation.

Figure 9 represents the format of the data correction instruction word used by the decode/select and pixel data averaging stages of Figure 8.

Figure 10 illustrates an example of how the grouping of defective pixels within the detector array determines the selection of north/south or east/west pixel data averaging.

Figure 11 is a functional block diagram of the pixel data averaging stages of Figure 8.

Figure 12 is a functional block diagram of the data buffer stage of Figure 8.

Figure 13 is a timing diagram illustrating the relative timing and values of the data

scaling factors during a radiographic mode of operation.

Figure 14 is a functional block diagram of an alternative embodiment of the data

5　buffer stage of Figure 8.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, an X-ray imaging system 10 in accordance with the present

invention includes a detector cassette 12, a computer and control system 14, a user interface

10　16, a fluoroscopic display 18a and a radiographic display 18b, interconnected substantially as

shown.　A user controls the system 10 by way of a user interface 16 (e.g., graphical user

interface display, keyboard, mouse, etc.) which communicates with the computer and control

system 14.　Accordingly, the computer and control system 14 generates control signals 13a

for the detector cassette 12 which provides image data signals 13b in return.　(As desired,

15　one display monitor could be used to selectively display both fluoroscopic and radiographic

images, as well as the graphical user interface display image, e.g., all images could be

displayed simultaneously in a "windowed" format, or either a fluoroscopic image or a

radiographic image could be displayed along with a pull down menu bar, which menu bar

constitutes the graphical user interface providing for selection of fluoroscopic or radiographic

20　imaging.)

Following processing of such image data, the computer and control system 14

provides fluoroscopic image data 15a or radiographic image data 15b for display on a

fluoroscopic display 18a or a radiographic display 18b, respectively, depending upon the

selected mode of operation. The fluoroscopic display 18a preferably employs a phosphor

which has a relatively short persistence time, thereby reducing unwanted ghost images when

observing motion in the sequence of displayed images. The radiographic display 18b

preferably employs a phosphor which yields a bluish tint to gray levels and has a relatively

5   long persistence time, thereby replicating the bluish tint typically found in standard medical

X-ray film images and reducing unwanted flicker in the displayed image.

Referring to Figure 2, the detector cassette 12 is similar in external appearance to the

typical cassette which contains standard medical X-ray film and is, therefore, highly mobile

and easy to use as required for a radiographic mode of operation. A scintillation layer 20,

10   e.g., of cesium iodide (CsI), absorbs and converts impinging X-ray photons to visible light

photons for detection by photosensitive elements within the detector array 22, e.g., of

amorphous silicon (a-Si). The thickness of the scintillation layer 20 is selected so as to

absorb sufficient X-ray photons and produce sufficient visible photons so as to generate an

adequate SNR for fluoroscopic operation. Similarly, the columns, or "needles," of the

15   crystalline CsI are selected so as to have diameters sufficiently small to support the spatial

resolution sampling desired for radiographic operation.

The detector array 22 is designed in accordance with well known techniques into a

two dimensional array of microscopic squares referred to as picture elements, or "pixels."

Each pixel is composed of an addressable photosensitive element, such as a photodiode and

20   switching transistor combination. As discussed in more detail below, each pixel is accessed

in accordance with drive signals from off-array driver circuit assemblies 26a, 26b which

provide addressing control signals. In accordance with well known techniques, the lateral

dimensions of the photodiodes are made sufficiently small to provide the desired spatial

resolution imaging for radiographic operation and the capacitance of the photodiodes is designed to be sufficiently large to provide the desired signal handling capacity for accommodating the largest signal produced during radiographic operation.

The pixel data accessed by the driver circuits 26 are read out by a receiver, or

5   readout, circuit assembly 28, as discussed in more detail below. The receiver circuit assembly 28 and detector array 22 are mounted on opposing sides of a base plate 24. (The receiver circuit assembly 28 is placed beneath the array 22 so as to minimize the lateral size of the detector cassette 12 and thereby make the detector cassette 12 approximately the same size as a film cassette. If so desired, the driver circuits 26 can also be placed beneath the

10 array 22.)

Referring to Figure 3, the detector array 22, as noted above, is composed of a two dimensional array, or matrix, of photosensitive pixels 30 which, in a preferred embodiment, include a switching transistor 32 and a photodiode 34. The anode of the photodiode 34 is biased by a biasing voltage 35 to establish a capacitance for storing electrical charges which

15 accumulate due to the reception of incident light 21 from the scintillation layer 20 (Figure 2). When the pixel 30 is accessed, a row address signal 31 from the array driver circuit 26 (discussed in more detail below) drives the gate of the switching transistor 32 (TFT), thereby providing a column data signal 33 representing the stored charge from the photodiode 34. This signal 33 is received and buffered by a charge sensitive amplifier within the receiver

20 circuit assembly 28 (discussed in more detail below).

Each row address signal 31 is asserted for a predetermined period of time, referred to as "line time." During assertion of each row address signal 31, the signal 33 from each pixel along that row is transmitted via the column data lines to the receiver circuit assembly

28 where the signal 33 on each data line is received and buffered by a corresponding charge

sensitive amplifier (discussed in more detail below). Hence, an entire row of image data is

captured in one line time period. With each subsequent line time period, a subsequent row

of image data is captured. At the end of a "frame time" period, the entire image has been

5 captured. In this manner, each pixel contained in the entire active detection area is sampled

individually.

Based upon the foregoing, and in accordance with the more detailed discussions of

the driver 26 and receiver 28 circuit assemblies which follow, it can be seen that the pixel

array supports multiple modes of operation. For example, during radiographic operation,

10 the pixel data is sampled on a pixel-by-pixel basis as discussed above. However, during

fluoroscopic operation, pixel data access can be accelerated, albeit with a reduction in spatial

resolution. This can be done by combining, or "binning," multiple pixels to produce "super

pixels." For example, a two-by-two pixel subset in which two rows and columns of pixels

are combined can be created by addressing two adjacent rows and two adjacent columns of

15 pixels at one time, with the driver circuit assembly 26 performing the simultaneous row

addressing and the receiver circuit assembly 28 performing the column line signal

combining. Hence, while the spatial resolution is reduced accordingly, significantly less

time will be required to capture the image, thereby allowing fluoroscopic imaging to be

performed.

20 This use of super pixels can also be done in a more selective manner. For example,

image acquisition in a fluoroscopic magnification mode can be performed when only a

portion of the active detection area is of interest. During such operation, the rows outside

the region of interest are addressed at a rapid rate or skipped entirely, while the rows within

12

the region of interest are addressed at a slower rate. The overall time to sequence through or

skip past all of the rows, i.e., the frame time, can remain equal to the frame time associated

with the fluoroscopic normal mode. However, due to the increased time available within the

region of interest, the super pixels within such region can be reduced in size, thereby

5   increasing the spatial resolution. (Appropriate combining of column line signals is also used

accordingly.) Hence, the smaller the size of the super pixel in the region of interest, the

higher the apparent magnification. (A smaller area of the detector is captured when

operating in fluoroscopic magnification mode than when operating in fluoroscopic normal

mode, but the display area remains the same, thereby producing an apparent magnification.)

10   Referring to Figure 4, the driver circuit assembly 26 includes a local controller 40 for

receiving control signals 13aa from the computer and control system 14 (Figure 1), plus a

series of gate drivers 42 for providing the row addressing signals 31. These gate drivers 42

can be operated in the manner of shift registers or, alternatively, be individually

programmed as desired according to the mode of operation using the control signals 41 from

15   the local controller 40. For example, during radiographic operation, the driver circuits 42

can be programmed such that the row 1 addressing signal 31(1) is asserted while the

remaining row addressing signals are de-asserted. Immediately following the next line

synchronization cycle, the row 1 signal is de-asserted and the row 2 signal is asserted, while

the remaining row signals are de-asserted. This successive assertion and de-assertion of

20   signals is repeated until all rows have been addressed. During fluoroscopic operation, the

foregoing assertion and de-assertion sequence is repeated, with the exception that multiple

adjacent row address signals are asserted at one time for creating super pixels, as discussed

above.

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Referring to Figure 5, the receiver circuit assembly 28 includes a local controller 50

for receiving control signals 13ab from the computer and control system 14 (Figure 1) and

generating local control signals 51. In accordance with its local control signals 51a, a

number of readout circuits 52 (discussed in more detail below), the number of which

5   depends upon the number of columns to be read out from the detector array 22, receives the

column data signals 33. The outputs 53 from the readout circuits 52 are buffered by

respective transimpedance amplifiers 54. These transimpedance amplifiers 54 are controlled

by local control signals 51b for purposes of controlling their offset and gain characteristics

(discussed in more detail below). The buffered column data signals 55 are converted by

10   analog-to-digital converters (ADCs) 56. The resulting digitized column data signals 57 are

then multiplexed by a multiplexor. The resulting multiplexed data signals 59 are buffered by

a data transmitter 60 for transmission to the computer and control system 14.

The control signals 51b for the transimpedance amplifiers 54 are used to selectively

optimize the offset and gain characteristics of the amplifiers 54. This allows the amplifiers

15   54 to be biased to match the respective output signal ranges of the amplifiers 54 to the input

signal ranges of the corresponding ADCs 56.

Referring to Figure 6, the readout circuits 52 collectively include multiple input

preamplifiers 64, pipelined sample and hold circuits 66 and output multiplexors 68,

interconnected substantially as shown. The control signals 51a from the local controller 50

20   (Figure 5) control the preamplifiers 64, pipelined sample and hold circuits 66 and a

multiplexor controller 62 which, in turn, controls the multiplexors 68 via multiplexor control

signals 63. The preamplifiers 64 receive the column data signals 33 with charge sensitive

amplifiers and provide the aforementioned binning capability for creating super pixels (in

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14

conjunction with the multiple row addressing capability of the array driver circuit 26 (Figure 4) as discussed above). The charge sensitive amplifiers are discussed in more detail in copending, commonly assigned U.S. patent application no. 08/758,538, entitled "Charge Sensitive Amplifier With High Common Mode Signal Rejection," filed November 29, 1996,

5   the disclosure of which is incorporated herein by reference. (The pixel binning capability provided by the preamplifiers is discussed in more detail below in connection with Figure 7.)

The buffered output signals 65aa, 65ba, 65ca, from the preamplifiers 64, are sampled using correlated double sampling by the pipelined sample and hold circuits 66 in accordance with their respective control signals 51ab. These pipelined sample and hold circuits 66 are

10   described in more detail in copending, commonly assigned U.S. patent application no. 08/758,536, entitled "Pipelined Sample and Hold Circuit With Correlated Double Sampling," filed November 29, 1996, the disclosure of which is incorporated herein by reference.

The sampled data signals 67 are multiplexed by their respective multiplexors 68 to

15   provide the final output signal 53. These multiplexors 68 operate in an analog current mode and are described in more detail in copending, commonly assigned U.S. patent application no. 08/758,528, entitled "Current Mode Analog Signal Multiplexor," November 29, 1996, the disclosure of which is incorporated herein by reference.

Referring to Figure 7, the aforementioned pixel binning capability with respect to the

20   column data can be described as follows. For purposes of this explanation, the second 64b, third 64c and fourth 64d preamplifier circuits are illustrated to represent the interconnection among adjacent preamplifiers 64. Internal to each preamplifier 64 is the aforementioned charge sensitive amplifier 70 which receives the column data signal 33. The buffered

column data signal 71 is coupled by a series coupling capacitor 72 to a summing node 78 for

selectively being summed with the buffered and capacitively coupled column data signal

from its adjacent preamplifier circuit 64. For example, if one-by-two super pixels were

being used, then the third and fourth pixels would be binned together by appropriately

5   asserting and de-asserting the control signals in signal sets 51aac and 51aad (and their inverse

equivalents via inverters 80c and 80d) so that switches 74c, 74e and 76d are opened and

switches 74d and 76c are closed. Accordingly, the buffered and capacitively coupled data

signal 65db from the fourth preamplifier 64d is summed with that of the third preamplifier

64c at its summing mode 78c for outputting as binned pixel data signal 65ca.

10   Referring to Figure 8, that portion 14a of the computer and control system 14 (Figure

1) responsible for processing the image data for display in accordance with the selected mode

of operation functions as follows. The sampled image data 13ba from the detector cassette

12 (Figure 1) is detected by a data detection stage 100. The data detection stage 100

monitors selected portions of the frame of incoming data and, in addition to passing the

15   incoming data 101a on to the next stage, generates a data present status signal 101b for use

elsewhere within the system (as discussed in more detail below).

          The buffered sampled image data 101a is corrected by an offset and gain correction

stage 104 using offset and gain correction data 103b, 103c stored in a memory 102. Such

offset and gain correction data 103b, 103c can be acquired in accordance with well known

20   techniques. For example, the offset correction data, used to correct for the effects of

leakage currents within the detector array 22 (Figure 2), can be collected by processing dark

frames of pixel data (no X-ray photons received) and inputted as a portion of pixel mapped

data 103a to the memory 102. The gain correction data, used for normalizing the gain

profile of the detector array 22, can be collected by processing frames of pixel data

generated when receiving an unobstructed X-ray field, and inputted as a portion of pixel

mapped data 103a to the memory 102. Such data is used to correct for variations in pixel

quantum efficiency and the two dimensional gain profile of the detector array 22 together

5   with its associated receiver circuitry 28.

In addition to the offset and gain information, one of the correction data words 103c

(e.g., corresponding to that normally used for gain correction data) also includes pixel flag

data and pixel data averaging instruction bits which identify, on a pixel-by-pixel basis, which

pixels, if any, are defective and the nature of such defect and, therefore, require the use of

10   either north/south or east/west averaging. Such pixel flag data can be collected in

accordance with well known techniques. For example, defective pixels can be identified

while collecting the offset and/or gain correction data.

Referring to Figure 9, the format of the correction data word 103c corresponding to a

bad pixel is as shown. (It should be understood that other selected bits within the word 103c

15   can be used, as desired). The most significant bit is used to identify the state of the pixel,

i.e., whether the pixel represents valid data or is defective and, therefore, represents invalid

data. Other bits, e.g., bits 10 and 5, are used to indicate whether north/south or east/west

averaging is to be performed. When the pixel data flag identifies the pixel as containing

valid data, the remaining bits contain the actual offset or gain correction information to be

20   used by the offset and gain correction stage 104.

Referring to Figure 10, the decision criteria for determining whether north/south or

east/west pixel data averaging is to be performed can be explained as follows. In this

example, a group of four defective pixels DP1-DP4 have been identified in columns X-1

through X+1 and rows Y-1 and Y, as shown. For this configuration of defective pixels, the

data correction words 103c corresponding to these defective pixels, in addition to containing

asserted pixel flags identifying these pixels as being defective, will contain asserted

north/south and east/west averaging instruction bits. For defective pixels DP2 and DP4, a

5   north/south averaging will be performed using the pixel data immediately above and below

in columns X-1 and X+1. Since this portion of columns X-1 and X+1 contain "good" pixel

data, the defective pixels DP1 and DP3 will be processed using east/west averaging. It is

preferred that an east/west average be followed by a north/south and thereafter followed by a

second east/west average to allow different arrangements of defective pixels to be corrected.

10   Referring again to Figure 8, the offset and gain correction stage 104 processes the

incoming data 101a on a pixel-by-pixel basis in accordance with the correction data 103b,

103c regardless of whether any such data is identified as originating from a bad pixel. The

resulting corrected data 105 is then provided, along with the one correction data word 103c

to a decode/select circuit 106. If, according to the pixel flag data within the correction data

15   word 103c from the memory 102, the corrected pixel data 105 did not originate from a

defective pixel, the decode/select circuit 106 provides the corrected pixel data 105 as its

output signal 107. If, however, the pixel flag data identify the "corrected data" 105 as

having originated from a defective pixel, the decode/select circuit 106 provides the

correction data 103c from the memory 102 as its output signal 107 for dynamic processing

20   along with other valid corrected pixel data by the remainder of this processing section 14a.

           The data 107 from the decode/select stage 106 is then processed, in accordance with

the north/south and east/west averaging instruction bits discussed above, by a north/south

averaging circuit 108 or an east/west averaging circuit 110. For example, if the selected

data 107 contains an instruction bit identifying north/south averaging as being required, the

north/south averaging stage 108 produces appropriately averaged data 109 which is then

simply passed through the east/west averaging stage 110 without further processing.

However, if the selected data 107 contains an instruction bit identifying east/west averaging

5   as being required, the selected data 107 is simply passed through the north/south averaging

stage 108 and presented to the east/west averaging stage 110 for appropriate processing

therein.

    Referring to Figure 11, the averaging function performed by the north/south 108 and

east/west 110 averaging stages can be described as follows. The incoming data 107/109 is

10   inputted continuously to a delay line 120 (e.g., a shift register). For the north/south

averaging stage 108, this delay line 120 is large enough to contain slightly more than two

rows of pixel data, while for the east/west averaging stage 110, the delay line 120 need only

be large enough to accommodate three or more pixels worth of data. When a data word

107/109 containing an asserted averaging instruction bit which corresponds to that particular

15   averaging stage 108/110 is encountered, it is provided as an output signal 121a to a

decode/select stage 124 when it has reached the approximate midpoint of the delay line 120.

    Upon receiving this signal 121a, the decode/select stage 124, recognizing the

instruction, uses the averaged pixel data 123 provided by a data averaging stage 122. (The

data averaging operation performed by this stage 122 can be done in accordance with any of

20   several well known techniques, e.g., interpolation of selected adjacent pixel data.) If,

however, this midpoint signal 121a from the delay line 120 does not contain an asserted

averaging instruction bit, but, instead, simply contains normal pixel data, the decode/select

stage 124 will ignore the averaged pixel data 123 constantly being provided by the data

19

averaging stage 122 and simply provide this pixel data signal 121a as its output data signal 109/111.

Referring again to Figure 8, the final averaged pixel data 111 is then selectively processed by a data buffer/filter 112. The operation of this data buffer filter 112 for the

5   different modes of operation can be explained as follows with reference to Figures 12 and 13. A preferred embodiment 112a of the data buffer/filter 112 includes an adder 130, a memory (e.g., random access memory) 132, two scaling circuits (e.g., multipliers) 134, 136, and two data registers 138, 140. The memory 132 is used to continuously receive and store the output data 113 on a frame-by-frame basis and provide such stored data in a first-

10   in, first-out manner to one of the scaling circuits 136. The data registers 138, 140 contain data corresponding to scaling factors α and β for scaling the present pixel data 111 and corresponding prior pixel data 133 (i.e., from a previous frame), respectively. The data registers 138, 140 use the aforementioned data present status signal 101b, a mode control signal 17a (originating from within the computer and control system 14) and an α/β

15   programming signal 149 for establishing the values of the α 139 and β 141 data provided to the scaling circuits 134, 136. The mode control signal 17a identifies whether a still or motion image operation is to be performed, while the α/β programming signal 149 can be used to program the actual values for α and β.

When operating in a still image (e.g., radiographic) mode, the α data 139 and β data

20   141 are initialized at unity and zero, respectively. When the data present status signal 101b indicates that valid active data has begun being received, the β data 141 is switched from zero to unity. Accordingly, scaled data sets 135 and 137 are equal to the present frame pixel data 111 and prior frame pixel data 133, respectively, thereby resulting in frame summation.

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This summation of prior and present frames of pixel data is done to generate the complete data set for display and is necessary since all data associated with a still image is generally not captured in a single reading of one frame of data, as represented in Figure 13. Once the data present status signal 101b has indicated that valid active data is no longer being

5   received, and after one additional frame of data has been collected, the α data 138 is reset to zero, while the β data 141 remains at unity.

When operating in a motion image (e.g., fluoroscopic) mode, the present data frame scaling factor α 137 is set equal to a predetermined value between zero and unity. Such a value can be established empirically to provide a video display with the desired

10 characteristics. The prior data frame scaling factor β 141 is set at a value which is also between zero and unity and is equal to $1-\alpha$. Hence, the output data 113 to be used for display purposes is composed primarily of the present frame of pixel data summed with a small portion of the prior frame of pixel data as stored by the memory 132. This has the effect of slightly increasing the SNR of the displayed frame as compared to the frame as

15 captured by the detector array 22. (Also, it has the additional effect of smoothing out any observable motion within the displayed image).

Referring again to Figure 8, the buffered and/or filtered pixel data 113 is used to address a lookup table 114 for purposes of mapping the input pixel data 113 to pixel data 15a/15b which is appropriately scaled for the particular display device being used.

20 Alternatively, this output stage 114 can include additional circuitry, as desired, to provide actual video signals for directly driving a display monitor.

Referring to Figure 14, an alternative embodiment 112b of the data buffer/filter stage 112 can be implemented as shown. (Those elements which correspond to those in the

embodiment 112a of Figure 12 are identified with the same numeric designators.) This embodiment 112b can be used where the α and β scaling factor data has been inserted or encoded in some manner within the incoming data stream 111. Accordingly, a shift register 150 can be used to buffer and delay the actual pixel data while the α data 151a and β data

5   151b are removed and forwarded on to the scaling circuits 134, 136. An encode logic circuit 152 can be used to provide appropriate control signals 153, in accordance with the mode control signal 17a, to the shift register 150.

Various other modifications and alterations in the structure and method of operation of this invention will be apparent to those skilled in the art without departing from the scope

10   and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. It is intended that the following claims define the scope of the present invention and that structures and methods within the scope of these claims and their equivalents be covered thereby.

22

WHAT IS CLAIMED IS:

1.   An apparatus including a multiple mode X-ray imaging system for supporting

multiple X-ray image display modes by providing X-ray image signals having selectable

spatial resolutions in a still image mode or an image motion mode with correction for

5   defective pixels individually or in groups, comprising:

a detector array configured to receive a plurality of detector control signals

and in accordance therewith

receive and convert a plurality of X-ray photons corresponding to a

two-dimensional image into a first plurality of image signals representing a

10   first two-dimensional array which includes a first plurality of rows and a first

plurality of columns of pixels which together correspond to said two-

dimensional image and which individually correspond to respective portions of

said two-dimensional image, and

provide a second plurality of image signals representing a second two-

15   dimensional array which includes a second plurality of rows and said first

plurality of columns of super pixels which selectively represent respective

individual ones or multiple adjacent ones of said first plurality of rows of

pixels and respective individual ones of said first plurality of columns of

pixels, respectively;

20   a plurality of detector array receiver circuits, coupled to said detector array,

configured to receive a plurality of receiver control signals and in accordance

therewith receive and combine said second plurality of image signals and in

accordance therewith provide a third plurality of image signals representing a third

two-dimensional array which includes said second plurality of rows and a second

plurality of columns of super pixels which selectively represent respective individual

ones of said second plurality of rows of super pixels and respective individual ones or

multiple adjacent ones of said first plurality of columns of super pixels, respectively;

5   a first data processing circuit, coupled to said plurality of detector array

receiver circuits, configured to receive and process together said third plurality of

image signals with a corresponding plurality of successive sets of correction data and

in accordance therewith provide a plurality of successive sets of corrected image data,

wherein said plurality of successive sets of correction data represents a plurality of

10   correction factors, each one of said plurality of correction factors corresponds to a

respective one of said plurality of super pixels and each one of said plurality of

successive sets of correction data includes a first data subset which indicates whether

said respective one of said plurality of super pixels is defective;

          a first data selection circuit, coupled to said first data processing circuit,

15   configured to receive and select between individual ones of said plurality of

successive sets of corrected image data and individual ones of said corresponding

plurality of successive sets of correction data and in accordance therewith provide a

first plurality of successive sets of selected data, wherein an individual one of said

first plurality of successive sets of selected data includes a corresponding individual

20   one of said plurality of successive sets of correction data when said first data subset

indicates that said corresponding respective one of said plurality of pixels is

defective, and wherein said individual one of said first plurality of successive sets of

selected data includes a corresponding one of said plurality of successive sets of

24

corrected image data when said first data subset does not indicate that said

corresponding respective one of said plurality of pixels is defective;

a data scaling and summing circuit, coupled to said first data selection circuit,

configured to receive and scale said first plurality of successive sets of selected data,

5   receive and scale a stored data sum signal and sum said scaled first plurality of

successive sets of selected data and said scaled stored data sum signal and in

accordance therewith provide a data sum signal, wherein said first plurality of

successive sets of selected data is scaled in accordance with a first scaling factor and

said stored data sum signal is scaled in accordance with a second scaling factor, and

10   wherein said first plurality of successive sets of selected data includes a plurality of

successive sets of image data, and further wherein each one of said plurality of

successive sets of image data includes a plurality of super pixel data with active and

inactive data states and which corresponds to said third two-dimensional array; and

a data memory circuit, coupled to said data scaling and summing circuit,

15   configured to receive and selectively store said data sum signal and in accordance

therewith provide said stored data sum signal;

wherein said data scaling and summing circuit and said data memory circuit

cooperatively operate in one of a plurality of operational modes during said reception

of said first plurality of successive sets of selected data;

20   wherein, in a first one of said plurality of operational modes,

said first scaling factor has a value which is between zero and unity,

and

said second scaling factor has a value which equals a difference

between unity and said first scaling factor value; and

wherein, in a second one of said plurality of operational modes,

said first scaling factor has a value which is initially unity when a first

one of said plurality of successive sets of image data is in said inactive data

state, remains unity when a subsequent second one of said plurality of

successive sets of image data is in said active data state and becomes zero

when a further subsequent third one of said plurality of successive sets of

image data is in said inactive data state, and

said second scaling factor has a value which is initially zero, becomes

unity when said subsequent second one of said plurality of successive sets of

image data is in said active data state and remains unity thereafter.

2.   An apparatus including a multiple mode X-ray detector system for supporting

multiple X-ray image display modes by providing X-ray image signals having selectable

spatial resolutions, comprising:

a detector array configured to receive a plurality of detector control signals

and in accordance therewith

receive and convert a plurality of X-ray photons corresponding to a

two-dimensional image into a first plurality of image signals representing a

first two-dimensional array which includes a first plurality of rows and a first

plurality of columns of pixels which together correspond to said two-

dimensional image and which individually correspond to respective portions of

said two-dimensional image, and

26

provide a second plurality of image signals representing a second two-dimensional array which includes a second plurality of rows and said first plurality of columns of super pixels which selectively represent respective individual ones or multiple adjacent ones of said first plurality of rows of

5   pixels and respective individual ones of said first plurality of columns of pixels, respectively; and

a plurality of detector array receiver circuits, coupled to said detector array, configured to receive a plurality of receiver control signals and in accordance therewith receive and combine said second plurality of image signals and in

10   accordance therewith provide a third plurality of image signals representing a third two-dimensional array which includes said second plurality of rows and a second plurality of columns of super pixels which selectively represent respective individual ones of said second plurality of rows of super pixels and respective individual ones or multiple adjacent ones of said first plurality of columns of super pixels, respectively;

15   wherein said plurality of detector array receiver circuits comprises a plurality of capacitive switching circuits configured to receive a portion of said plurality of receiver control signals and in accordance therewith receive and combine selected ones of said second plurality of image signals and in accordance therewith provide said third plurality of image signals.

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3.   The apparatus of claim 2, wherein said detector array comprises a two-dimensional array of a plurality of pixel elements, and wherein each one of said plurality of pixel elements comprises a light sensitive circuit configured to:

27

receive one of said plurality of detector control signals and in accordance

therewith receive and convert a portion of said plurality of X-ray photons into one of

said first plurality of image signals; and

receive another one of said plurality of detector control signals and said one of

5   said first plurality of image signals and in accordance therewith provide one of said

second plurality of image signals.

4.   The apparatus of claim 3, wherein said light sensitive circuit comprises:

a photodiode configured to receive said one of said plurality of detector

10   control signals and in accordance therewith receive and convert said portion of said

plurality of X-ray photons into one of said first plurality of image signals; and

a switching transistor, coupled to said photodiode, configured to receive said

another one of said plurality of detector control signals and said one of said first

plurality of image signals and in accordance therewith provide one of said second

15   plurality of image signals.

5.   The apparatus of claim 2, further comprising a plurality of sample and hold circuits,

coupled to said plurality of capacitive switching circuits, configured to receive another

portion of said plurality of receiver control signals and in accordance therewith sample and

20   hold said second plurality of electrical charges.

6.   The apparatus of claim 2, further comprising a plurality of detector array driver

circuits, coupled to said detector array, configured to receive a plurality of driver control

28

signals and in accordance therewith provide said plurality of detector control signals.

7.   The apparatus of claim 6, wherein said plurality of detector array driver circuits

comprises a plurality of demultiplexors configured to receive a portion of said plurality of

5   driver control signals and in accordance therewith provide a plurality of row addressing

signals as a portion of said plurality of detector control signals.

8.   An apparatus including a data processing system for processing a serial stream of

multiple bit data sets which represent an array of pixels corresponding to a two-dimensional

10   image including correcting for defective pixels individually or in groups, comprising:

a first data processing circuit configured to receive and process together a

plurality of successive sets of image data with a corresponding plurality of successive

sets of correction data and in accordance therewith provide a plurality of successive

sets of corrected image data, wherein said plurality of successive sets of image data

represents a plurality of pixels corresponding to a two-dimensional image, said

15   plurality of successive sets of correction data represents a plurality of correction

factors, each one of said plurality of correction factors corresponds to a respective

one of said plurality of pixels and each one of said plurality of successive sets of

correction data includes a first data subset which indicates whether said respective

20   one of said plurality of pixels is defective; and

a first data selection circuit, coupled to said first data processing circuit,

configured to receive and select between individual ones of said plurality of

successive sets of corrected image data and individual ones of said corresponding

plurality of successive sets of correction data and in accordance therewith provide a

first plurality of successive sets of selected data, wherein an individual one of said

first plurality of successive sets of selected data includes a corresponding individual

one of said plurality of successive sets of correction data when said first data subset

5   indicates that said corresponding respective one of said plurality of pixels is

defective, and wherein said individual one of said first plurality of successive sets of

selected data includes a corresponding one of said plurality of successive sets of

corrected image data when said first data subset does not indicate that said

corresponding respective one of said plurality of pixels is defective.

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9.   The apparatus of claim 8, wherein each one of said plurality of successive sets of

correction data further includes a second data subset which indicates which one of a plurality

of substitute pixel values is to be used for said defective corresponding respective one of said

plurality of pixels, and further comprising:

15   a second data processing circuit, coupled to said first data selection circuit,

configured to receive and store said first plurality of successive sets of selected data

and generate a first set of substitute data, wherein said first set of substitute data

represents a first one of said plurality of substitute pixel values and is computed in

accordance with selected ones of said stored first plurality of successive sets of

20   selected data; and

a second data selection circuit, coupled to said second data processing circuit,

configured to receive and select between one of said stored first plurality of

successive sets of selected data and said first set of substitute data and in accordance

30

therewith provide a second plurality of successive sets of selected data, wherein an individual one of said second plurality of successive sets of selected data includes said first set of substitute data when said second data subset indicates that said first one of said plurality of substitute pixel values is to be used for said defective corresponding respective one of said plurality of pixels, and wherein said individual one of said second plurality of successive sets of selected data includes said one of said stored first plurality of successive sets of selected data when said second data subset does not indicate that said first one of said plurality of substitute pixel values is to be used for said defective corresponding respective one of said plurality of pixels.

10.   The apparatus of claim 9, wherein said second data processing circuit comprises:

a delay line configured to receive and store said first plurality of successive sets of selected data and in accordance therewith provide a plurality of successively delayed sets of selected data, wherein a temporally intermediate one of said plurality of successively delayed sets of selected data is provided as said one of said stored first plurality of successive sets of selected data; and

a data averaging circuit, coupled to said delay line, configured to receive and average first and second ones of said plurality of successively delayed sets of selected data and in accordance therewith provide said first set of substitute data, wherein said first and second ones of said plurality of successively delayed sets of selected data are temporally precedent and subsequent to said temporally intermediate one of said plurality of successively delayed sets of selected data.

11.   The apparatus of claim 9, further comprising:

        a third data processing circuit, coupled to said second data selection circuit,

configured to receive and store said second plurality of successive sets of selected

data and generate a second set of substitute data, wherein said second set of substitute

5   data represents a second one of said plurality of substitute pixel values and is

computed in accordance with selected ones of said stored second plurality of

successive sets of selected data; and

        a third data selection circuit, coupled to said third data processing circuit,

configured to receive and select between one of said stored second plurality of

10   successive sets of selected data and said second set of substitute data and in

accordance therewith provide a third plurality of successive sets of selected data,

wherein an individual one of said third plurality of successive sets of selected data

includes said second set of substitute data when said second data subset indicates that

said second one of said plurality of substitute pixel values is to be used for said

15   defective corresponding respective one of said plurality of pixels, and wherein said

individual one of said third plurality of successive sets of selected data includes said

one of said stored second plurality of successive sets of selected data when said

second data subset does not indicate that said second one of said plurality of substitute

pixel values is to be used for said defective corresponding respective one of said

20   plurality of pixels.

12.   The apparatus of claim 8, further comprising a data storage circuit, coupled to said

first data processing circuit and said first data selection circuit, configured to store and

provide said corresponding plurality of successive sets of correction data.

13.   An apparatus including a digital data buffer and filter for selectively storing image

pixel data, combining new incoming image pixel data with previously stored image pixel

5   data and providing such combined image pixel data for display thereof in a still image mode

or an image motion mode, comprising:

a data scaling and summing circuit configured to receive and scale an input

data signal, receive and scale a stored data sum signal and sum said scaled input data

signal and said scaled stored data sum signal and in accordance therewith provide a

10   data sum signal, wherein said input data signal is scaled in accordance with a first

scaling factor and said stored data sum signal is scaled in accordance with a second

scaling factor, and wherein said input data signal includes a plurality of successive

sets of image data, and further wherein each one of said plurality of successive sets of

image data includes a plurality of pixel data with active and inactive data states and

15   which corresponds to a two-dimensional image having a two-dimensional array

including a plurality of rows and a plurality of columns of pixels which together

correspond to said two-dimensional image and which individually correspond to

respective portions of said two-dimensional image; and

a data memory circuit, coupled to said data scaling and summing circuit,

20   configured to receive and selectively store said data sum signal and in accordance

therewith provide said stored data sum signal;

wherein said data scaling and summing circuit and said data memory circuit

cooperatively operate in one of a plurality of operational modes during said reception

of said input data signal;

wherein, in a first one of said plurality of operational modes,

said first scaling factor has a value which is between zero and unity,

and

said second scaling factor has a value which equals a difference

between unity and said first scaling factor value; and

wherein, in a second one of said plurality of operational modes,

said first scaling factor has a value which is initially unity when a first

one of said plurality of successive sets of image data is in said inactive data

state, remains unity when a subsequent second one of said plurality of

successive sets of image data is in said active data state and becomes zero

when a further subsequent third one of said plurality of successive sets of

image data is in said inactive data state, and

said second scaling factor has a value which is initially zero, becomes

unity when said subsequent second one of said plurality of successive sets of

image data is in said active data state and remains unity thereafter.

14.   The apparatus of claim 13, wherein said data scaling and summing circuit comprises

an arithmetic logic unit.

15.   The apparatus of claim 13, wherein said data scaling and summing circuit comprises:

a first data scaling circuit configured to receive a first scaling control signal

which represents said first scaling factor and in accordance therewith receive and

34

scale said input data signal and in accordance therewith provide a first scaled data

signal;

a second data scaling circuit configured to receive a second scaling control

signal which represents said second scaling factor and in accordance therewith receive

and scale said stored data sum signal and in accordance therewith provide a second

scaled data signal; and

a data summing circuit, coupled to said first and second data scaling circuits,

configured to receive and sum said first and second scaled data signals and in

accordance therewith provide said data sum signal.

16.   The apparatus of claim 13, wherein said data memory circuit comprises a random

access memory unit.

17.   The apparatus of claim 15, further comprising first and second control signal sources

configured to provide said first and second scaling control signals.

18.   The apparatus of claim 15, further comprising a signal separator circuit configured to

receive an incoming data signal and separate therefrom said first and second scaling control

signals and in accordance therewith provide said input data signal and said first and second

scaling control signals.

19.   An apparatus including a multiple mode X-ray imaging system for supporting

multiple X-ray image display modes by providing X-ray image signals having selectable

spatial resolutions in a still image mode or an image motion mode including correcting for

defective pixels individually or in groups, comprising:

a detector array configured to receive a plurality of detector control signals

and in accordance therewith receive and convert a plurality of X-ray photons into a

5   first plurality of image signals, wherein

said plurality of X-ray photons correspond to a two-dimensional image

represented by a first two-dimensional array which includes a first plurality of

rows and a first plurality of columns of pixels which together correspond to

said two-dimensional image and which individually correspond to respective

10   portions of said two-dimensional image, and

said first plurality of image signals represent a second two-dimensional

array which includes a second plurality of rows and said first plurality of

columns of super pixels which selectively represent respective individual ones

or multiple adjacent ones of said first plurality of rows of pixels and

15   respective individual ones of said first plurality of columns of pixels,

respectively;

a plurality of detector array receiver circuits, coupled to said detector array,

configured to receive a plurality of receiver control signals and in accordance

therewith receive and combine said first plurality of image signals and in accordance

20   therewith provide a second plurality of image signals representing a third two-

dimensional array which includes said second plurality of rows and a second plurality

of columns of super pixels which selectively represent respective individual ones of

said second plurality of rows of super pixels and respective individual ones or

36

multiple adjacent ones of said first plurality of columns of super pixels, respectively;

a first data processing circuit, coupled to said plurality of detector array receiver circuits, configured to receive and process together said second plurality of image signals with a corresponding plurality of successive sets of correction data and in accordance therewith provide a plurality of successive sets of corrected image data, wherein said plurality of successive sets of correction data represents a plurality of correction factors, each one of said plurality of correction factors corresponds to a respective one of said plurality of super pixels and each one of said plurality of successive sets of correction data includes a first data subset which indicates whether said respective one of said plurality of super pixels is defective;

a first data selection circuit, coupled to said first data processing circuit, configured to receive and select between individual ones of said plurality of successive sets of corrected image data and individual ones of said corresponding plurality of successive sets of correction data and in accordance therewith provide a first plurality of successive sets of selected data, wherein an individual one of said first plurality of successive sets of selected data includes a corresponding individual one of said plurality of successive sets of correction data when said first data subset indicates that said corresponding respective one of said plurality of pixels is defective, and wherein said individual one of said first plurality of successive sets of selected data includes a corresponding one of said plurality of successive sets of corrected image data when said first data subset does not indicate that said corresponding respective one of said plurality of pixels is defective;

a data scaling and summing circuit, coupled to said first data selection circuit,

configured to receive and scale said first plurality of successive sets of selected data,

receive and scale a stored data sum signal and sum said scaled first plurality of

successive sets of selected data and said scaled stored data sum signal and in

accordance therewith provide a data sum signal, wherein said first plurality of

5   successive sets of selected data is scaled in accordance with a first scaling factor and

said stored data sum signal is scaled in accordance with a second scaling factor, and

wherein said first plurality of successive sets of selected data includes a plurality of

successive sets of image data, and further wherein each one of said plurality of

successive sets of image data includes a plurality of super pixel data with active and

10   inactive data states and which corresponds to said third two-dimensional array; and

a data memory circuit, coupled to said data scaling and summing circuit,

configured to receive and selectively store said data sum signal and in accordance

therewith provide said stored data sum signal;

wherein said data scaling and summing circuit and said data memory circuit

15   cooperatively operate in one of a plurality of operational modes during said reception

of said first plurality of successive sets of selected data;

wherein, in a first one of said plurality of operational modes,

said first scaling factor has a value which is between zero and unity,

and

20   said second scaling factor has a value which equals a difference

between unity and said first scaling factor value; and

wherein, in a second one of said plurality of operational modes,

said first scaling factor has a value which is initially unity when a first

one of said plurality of successive sets of image data is in said inactive data

state, remains unity when a subsequent second one of said plurality of

successive sets of image data is in said active data state and becomes zero

when a further subsequent third one of said plurality of successive sets of

5   image data is in said inactive data state, and

said second scaling factor has a value which is initially zero, becomes

unity when said subsequent second one of said plurality of successive sets of

image data is in said active data state and remains unity thereafter.

10   20.   A method of providing X-ray image signals having selectable spatial resolutions in a

still image mode or an image motion mode including correcting for defective pixels

individually or in groups, comprising the steps of:

receiving a plurality of detector control signals and in accordance therewith:

receiving and converting a plurality of X-ray photons which

15   correspond to a two-dimensional image into a first plurality of image signals

which represent a first two-dimensional array including a first plurality of

rows and a first plurality of columns of pixels which together correspond to

said two-dimensional image and which individually correspond to respective

portions of said two-dimensional image, and

20   generating a second plurality of image signals which represent a

second two-dimensional array including a second plurality of rows and said

first plurality of columns of super pixels which selectively represent respective

individual ones or multiple adjacent ones of said first plurality of rows of

pixels and respective individual ones of said first plurality of columns of

pixels, respectively; and

receiving a plurality of receiver control signals and in accordance therewith

receiving and combining said second plurality of image signals and in accordance

5   therewith generating a third plurality of image signals which represent a third two-

dimensional array including said second plurality of rows and a second plurality of

columns of super pixels which selectively represent respective individual ones of said

second plurality of rows of super pixels and respective individual ones or multiple

adjacent ones of said first plurality of columns of super pixels, respectively;

10   receiving and processing together said third plurality of image signals with a

corresponding plurality of successive sets of correction data and in accordance

therewith generating a plurality of successive sets of corrected image data, wherein

said plurality of successive sets of correction data represents a plurality of correction

factors, each one of said plurality of correction factors corresponds to a respective

15   one of said plurality of super pixels and each one of said plurality of successive sets

of correction data includes a first data subset which indicates whether said respective

one of said plurality of super pixels is defective;

selecting between individual ones of said plurality of successive sets of

corrected image data and individual ones of said corresponding plurality of successive

20   sets of correction data and in accordance therewith generating a first plurality of

successive sets of selected data, wherein an individual one of said first plurality of

successive sets of selected data includes a corresponding individual one of said

plurality of successive sets of correction data when said first data subset indicates that

said corresponding respective one of said plurality of pixels is defective, and wherein said individual one of said first plurality of successive sets of selected data includes a corresponding one of said plurality of successive sets of corrected image data when said first data subset does not indicate that said corresponding respective one of said plurality of pixels is defective;

receiving and scaling said first plurality of successive sets of selected data, receiving and scaling a stored data sum signal and summing said scaled first plurality of successive sets of selected data and said scaled stored data sum signal and in accordance therewith generating a data sum signal, wherein said first plurality of successive sets of selected data is scaled in accordance with a first scaling factor and said stored data sum signal is scaled in accordance with a second scaling factor, and wherein said first plurality of successive sets of selected data includes a plurality of successive sets of image data, and further wherein each one of said plurality of successive sets of image data includes a plurality of super pixel data with active and inactive data states and which corresponds to said third two-dimensional array; and

selectively storing said data sum signal and in accordance therewith generating said stored data sum signal;

wherein said step of receiving and scaling said first plurality of successive sets of selected data, receiving and scaling a stored data sum signal and summing said scaled first plurality of successive sets of selected data and said scaled stored data sum signal and in accordance therewith generating a data sum signal and said step of selectively storing said data sum signal and in accordance therewith generating said stored data sum signal are cooperatively performed in one of a plurality of

41

performance modes during said reception of said first plurality of successive sets of

selected data;

wherein, in a first one of said plurality of performance modes,

said first scaling factor has a value which is between zero and unity,

5   and

said second scaling factor has a value which equals a difference

between unity and said first scaling factor value; and

wherein, in a second one of said plurality of performance modes,

said first scaling factor has a value which is initially unity when a first

10   one of said plurality of successive sets of image data is in said inactive data

state, remains unity when a subsequent second one of said plurality of

successive sets of image data is in said active data state and becomes zero

when a further subsequent third one of said plurality of successive sets of

image data is in said inactive data state, and

15   said second scaling factor has a value which is initially zero, becomes

unity when said subsequent second one of said plurality of successive sets of

image data is in said active data state and remains unity thereafter.

21.   A method of providing X-ray image signals having selectable spatial resolutions in a

20   still image mode or an image motion mode including correcting for defective pixels

individually or in groups, comprising the steps of:

receiving a plurality of detector control signals and in accordance therewith

receiving and converting a plurality of X-ray photons into a first plurality of image

signals, wherein

said plurality of X-ray photons correspond to a two-dimensional image represented by a first two-dimensional array which includes a first plurality of rows and a first plurality of columns of pixels which together correspond to

5   said two-dimensional image and which individually correspond to respective portions of said two-dimensional image, and

said first plurality of image signals represent a second two-dimensional array which includes a second plurality of rows and said first plurality of columns of super pixels which selectively represent respective individual ones

10   or multiple adjacent ones of said first plurality of rows of pixels and respective individual ones of said first plurality of columns of pixels, respectively;

receiving a plurality of receiver control signals and in accordance therewith receiving and combining said first plurality of image signals and in accordance

15   therewith generating a second plurality of image signals which represent a third two-dimensional array including said second plurality of rows and a second plurality of columns of super pixels which selectively represent respective individual ones of said second plurality of rows of super pixels and respective individual ones or multiple adjacent ones of said first plurality of columns of super pixels, respectively;

20   receiving and processing together said second plurality of image signals with a corresponding plurality of successive sets of correction data and in accordance therewith generating a plurality of successive sets of corrected image data, wherein said plurality of successive sets of correction data represents a plurality of correction

43

factors, each one of said plurality of correction factors corresponds to a respective

one of said plurality of super pixels and each one of said plurality of successive sets

of correction data includes a first data subset which indicates whether said respective

one of said plurality of super pixels is defective;

5   selecting between individual ones of said plurality of successive sets of

corrected image data and individual ones of said corresponding plurality of successive

sets of correction data and in accordance therewith generating a first plurality of

successive sets of selected data, wherein an individual one of said first plurality of

successive sets of selected data includes a corresponding individual one of said

10   plurality of successive sets of correction data when said first data subset indicates that

said corresponding respective one of said plurality of pixels is defective, and wherein

said individual one of said first plurality of successive sets of selected data includes a

corresponding one of said plurality of successive sets of corrected image data when

said first data subset does not indicate that said corresponding respective one of said

15   plurality of pixels is defective;

receiving and scaling said first plurality of successive sets of selected data,

receiving and scaling a stored data sum signal and summing said scaled first plurality

of successive sets of selected data and said scaled stored data sum signal and in

accordance therewith generating a data sum signal, wherein said first plurality of

20   successive sets of selected data is scaled in accordance with a first scaling factor and

said stored data sum signal is scaled in accordance with a second scaling factor, and

wherein said first plurality of successive sets of selected data includes a plurality of

successive sets of image data, and further wherein each one of said plurality of

44

successive sets of image data includes a plurality of super pixel data with active and

inactive data states and which corresponds to said third two-dimensional array; and

selectively storing said data sum signal and in accordance therewith generating

said stored data sum signal;

5   wherein said step of receiving and scaling said first plurality of successive sets

of selected data, receiving and scaling a stored data sum signal and summing said

scaled first plurality of successive sets of selected data and said scaled stored data

sum signal and in accordance therewith generating a data sum signal and said step of

selectively storing said data sum signal and in accordance therewith generating said

10   stored data sum signal are cooperatively performed in one of a plurality of

performance modes during said reception of said first plurality of successive sets of

selected data;

wherein, in a first one of said plurality of performance modes,

said first scaling factor has a value which is between zero and unity,

15   and

said second scaling factor has a value which equals a difference

between unity and said first scaling factor value; and

wherein, in a second one of said plurality of performance modes,

said first scaling factor has a value which is initially unity when a first

20   one of said plurality of successive sets of image data is in said inactive data

state, remains unity when a subsequent second one of said plurality of

successive sets of image data is in said active data state and becomes zero

when a further subsequent third one of said plurality of successive sets of

45

image data is in said inactive data state, and

said second scaling factor has a value which is initially zero, becomes

unity when said subsequent second one of said plurality of successive sets of

image data is in said active data state and remains unity thereafter.

5

22.   A method of providing X-ray image signals having selectable spatial resolutions,

comprising the steps of:

receiving a plurality of detector control signals and in accordance therewith:

receiving and converting a plurality of X-ray photons which

10   correspond to a two-dimensional image into a first plurality of image signals

which represent a first two-dimensional array including a first plurality of

rows and a first plurality of columns of pixels which together correspond to

said two-dimensional image and which individually correspond to respective

portions of said two-dimensional image, and

15   generating a second plurality of image signals which represent a

second two-dimensional array including a second plurality of rows and said

first plurality of columns of super pixels which selectively represent respective

individual ones or multiple adjacent ones of said first plurality of rows of

pixels and respective individual ones of said first plurality of columns of

20   pixels, respectively; and

receiving a plurality of receiver control signals and in accordance therewith

receiving and combining said second plurality of image signals and in accordance

therewith generating a third plurality of image signals which represent a third two-

46

dimensional array including said second plurality of rows and a second plurality of

columns of super pixels which selectively represent respective individual ones of said

second plurality of rows of super pixels and respective individual ones or multiple

adjacent ones of said first plurality of columns of super pixels, respectively;

5   wherein said second and third pluralities of image signals comprise first and

second pluralities of electrical charges, respectively; and

said step of receiving a plurality of receiver control signals and in accordance

therewith receiving and combining said second plurality of image signals and in

accordance therewith generating a third plurality of image signals comprises receiving

10   a portion of said plurality of receiver control signals and in accordance therewith

receiving and capacitively combining selected ones of said first plurality of electrical

charges and in accordance therewith generating said second plurality of electrical

charges.

15   23.   The method of claim 22, wherein said method of providing X-ray image signals

having selectable spatial resolutions comprises providing said X-ray image signals by using a

two-dimensional array of a plurality of pixel elements, and wherein for each one of said

plurality of pixel elements:

said step of receiving a plurality of detector control signals and in accordance

20   therewith receiving and converting a plurality of X-ray photons into a first plurality

of image signals comprises receiving one of said plurality of detector control signals

and in accordance therewith receiving and converting a portion of said plurality of

X-ray photons into one of said first plurality of image signals; and

47

said step of receiving a plurality of detector control signals and in accordance

therewith generating a second plurality of image signals comprises receiving another

one of said plurality of detector control signals and said one of said first plurality of

image signals and in accordance therewith generating one of said second plurality of

5   image signals.

24.   A method of providing X-ray image signals having selectable spatial resolutions,

comprising the steps of:

        receiving a plurality of detector control signals and in accordance therewith

10   receiving and converting a plurality of X-ray photons into a first plurality of image

signals, wherein:

                said plurality of X-ray photons correspond to a two-dimensional image

        represented by a first two-dimensional array which includes a first plurality of

        rows and a first plurality of columns of pixels which together correspond to

15   said two-dimensional image and which individually correspond to respective

        portions of said two-dimensional image, and

                said first plurality of image signals represent a second two-dimensional

        array which includes a second plurality of rows and said first plurality of

        columns of super pixels which selectively represent respective individual ones

20   or multiple adjacent ones of said first plurality of rows of pixels and

        respective individual ones of said first plurality of columns of pixels,

        respectively;

        receiving a plurality of receiver control signals and in accordance therewith

48

receiving and combining said first plurality of image signals and in accordance

therewith generating a second plurality of image signals which represent a

third two-dimensional array including said second plurality of rows and a

second plurality of columns of super pixels which selectively represent

5   respective individual ones of said second plurality of rows of super pixels and

respective individual ones or multiple adjacent ones of said first plurality of

columns of super pixels, respectively;

wherein said first and second pluralities of image signals comprise first and

second pluralities of electrical charges, respectively; and

10   said step of receiving a plurality of receiver control signals and in accordance

therewith receiving and combining said first plurality of image signals and in

accordance therewith generating a second plurality of image signals comprises

receiving a portion of said plurality of receiver control signals and in accordance

therewith receiving and capacitively combining selected ones of said first plurality of

15   electrical charges and in accordance therewith generating said second plurality of

electrical charges.

25.   The method of claim 24, wherein said method of providing X-ray image signals

having selectable spatial resolutions comprises providing said X-ray image signals by using a

20   two-dimensional array of a plurality of pixel elements, and wherein for each one of said

plurality of pixel elements said step of receiving a plurality of detector control signals and in

accordance therewith receiving and converting a plurality of X-ray photons into a first

plurality of image signals comprises receiving a portion of said plurality of detector control

49

signals and in accordance therewith receiving and converting a portion of said plurality of

X-ray photons into one of said first plurality of image signals.

26.   A method of processing a serial stream of multiple bit data sets

5   which represent an array of pixels corresponding to a two-dimensional image including

correcting for defective pixels individually or in groups, comprising the steps of:

receiving and processing together a plurality of successive sets of image data

with a corresponding plurality of successive sets of correction data and in accordance

therewith generating a plurality of successive sets of corrected image data, wherein

10   said plurality of successive sets of image data represents a plurality of pixels

corresponding to a two-dimensional image, said plurality of successive sets of

correction data represents a plurality of correction factors, each one of said plurality

of correction factors corresponds to a respective one of said plurality of pixels and

each one of said plurality of successive sets of correction data includes a first data

15   subset which indicates whether said respective one of said plurality of pixels is

defective; and

receiving and selecting between individual ones of said plurality of successive

sets of corrected image data and individual ones of said corresponding plurality of

successive sets of correction data and in accordance therewith generating a first

20   plurality of successive sets of selected data, wherein an individual one of said first

plurality of successive sets of selected data includes a corresponding individual one of

said plurality of successive sets of correction data when said first data subset indicates

that said corresponding respective one of said plurality of pixels is defective, and

50

wherein said individual one of said first plurality of successive sets of selected data

includes a corresponding one of said plurality of successive sets of corrected image

data when said first data subset does not indicate that said corresponding respective

one of said plurality of pixels is defective.

5

27.   The method of claim 26, wherein each one of said plurality of successive sets of

correction data further includes a second data subset which indicates which one of a plurality

of substitute pixel values is to be used for said defective corresponding respective one of said

plurality of pixels, and further comprising the steps of:

10   receiving and storing said first plurality of successive sets of selected data and

generating a first set of substitute data, wherein said first set of substitute data

represents a first one of said plurality of substitute pixel values and is computed in

accordance with selected ones of said stored first plurality of successive sets of

selected data; and

15   receiving and selecting between one of said stored first plurality of successive

sets of selected data and said first set of substitute data and in accordance therewith

generating a second plurality of successive sets of selected data, wherein an

individual one of said second plurality of successive sets of selected data includes said

first set of substitute data when said second data subset indicates that said first one of

20   said plurality of substitute pixel values is to be used for said defective corresponding

respective one of said plurality of pixels, and wherein said individual one of said

second plurality of successive sets of selected data includes said one of said stored

first plurality of successive sets of selected data when said second data subset does

51

not indicate that said first one of said plurality of substitute pixel values is to be used

for said defective corresponding respective one of said plurality of pixels.

28.   The method of claim 27, wherein said step of receiving and storing said first plurality

5   of successive sets of selected data and generating a first set of substitute data comprises:

receiving and storing said first plurality of successive sets of selected data and

in accordance therewith generating a plurality of successively delayed sets of selected

data, wherein a temporally intermediate one of said plurality of successively delayed

sets of selected data is outputted as said one of said stored first plurality of successive

10   sets of selected data; and

receiving and averaging first and second ones of said plurality of successively

delayed sets of selected data and in accordance therewith generating said first set of

substitute data, wherein said first and second ones of said plurality of successively

delayed sets of selected data are temporally precedent and subsequent to said

15   temporally intermediate one of said plurality of successively delayed sets of selected

data.

29.   The method of claim 27, further comprising the steps of:

receiving and storing said second plurality of successive sets of selected data

20   and generating a second set of substitute data, wherein said second set of substitute

data represents a second one of said plurality of substitute pixel values and is

computed in accordance with selected ones of said stored second plurality of

successive sets of selected data; and

52

receiving and selecting between one of said stored second plurality of

successive sets of selected data and said second set of substitute data and in

accordance therewith generating a third plurality of successive sets of selected data,

wherein an individual one of said third plurality of successive sets of selected data

5   includes said second set of substitute data when said second data subset indicates that

said second one of said plurality of substitute pixel values is to be used for said

defective corresponding respective one of said plurality of pixels, and wherein said

individual one of said third plurality of successive sets of selected data includes said

one of said stored second plurality of successive sets of selected data when said

10   second data subset does not indicate that said second one of said plurality of substitute

pixel values is to be used for said defective corresponding respective one of said

plurality of pixels.

30.   A method of selectively storing image pixel data, combining new incoming image

15   pixel data with previously stored image pixel data and providing such combined image pixel

data for display thereof in a still image mode or an image motion mode, comprising the steps

of:

receiving and scaling an input data signal, receiving and scaling a stored data

sum signal and summing said scaled input data signal and said scaled stored data sum

20   signal and in accordance therewith generating a data sum signal, wherein said input

data signal is scaled in accordance with a first scaling factor and said stored data sum

signal is scaled in accordance with a second scaling factor, and wherein said input

data signal includes a plurality of successive sets of image data, and further wherein

53

each one of said plurality of successive sets of image data includes a plurality of pixel

data with active and inactive data states and which corresponds to a two-dimensional

image having a two-dimensional array including a plurality of rows and a plurality of

columns of pixels which together correspond to said two-dimensional image and

5   which individually correspond to respective portions of said two-dimensional image;

and

       receiving and selectively storing said data sum signal and in accordance

therewith generating said stored data sum signal;

       wherein said step of receiving and scaling an input data signal, receiving and

10   scaling a stored data sum signal and summing said scaled input data signal and said

scaled stored data sum signal and in accordance therewith generating a data sum

signal and said step of receiving and selectively storing said data sum signal and in

accordance therewith generating said stored data sum signal are cooperatively

performed in one of a plurality of performance modes during said reception of said

15   input data signal;

       wherein, in a first one of said plurality of performance modes,

              said first scaling factor has a value which is between zero and unity,

and

              said second scaling factor has a value which equals a difference

20   between unity and said first scaling factor value; and

       wherein, in a second one of said plurality of performance modes,

              said first scaling factor has a value which is initially unity when a first

one of said plurality of successive sets of image data is in said inactive data

54

state, remains unity when a subsequent second one of said plurality of

successive sets of image data is in said active data state and becomes zero

when a further subsequent third one of said plurality of successive sets of

image data is in said inactive data state, and

5   said second scaling factor has a value which is initially zero, becomes

unity when said subsequent second one of said plurality of successive sets of

image data is in said active data state and remains unity thereafter.

31.   The method of claim 30, wherein said step of receiving and scaling an input data

10   signal, receiving and scaling a stored data sum signal and summing said scaled input data

signal and said scaled stored data sum signal and in accordance therewith generating a data

sum signal comprises:

              receiving a first scaling control signal which represents said first scaling factor

and in accordance therewith receiving and scaling said input data signal and in

15   accordance therewith generating a first scaled data signal;

              receiving a second scaling control signal which represents said second scaling

factor and in accordance therewith receiving and scaling said stored data sum signal

and in accordance therewith generating a second scaled data signal; and

              receiving and summing said first and second scaled data signals and in

20   accordance therewith generating said data sum signal.

32.   The method of claim 31, further comprising the step of receiving an incoming data

signal and separating therefrom said first and second scaling control signals and in

accordance therewith generating said input data signal and said first and second scaling
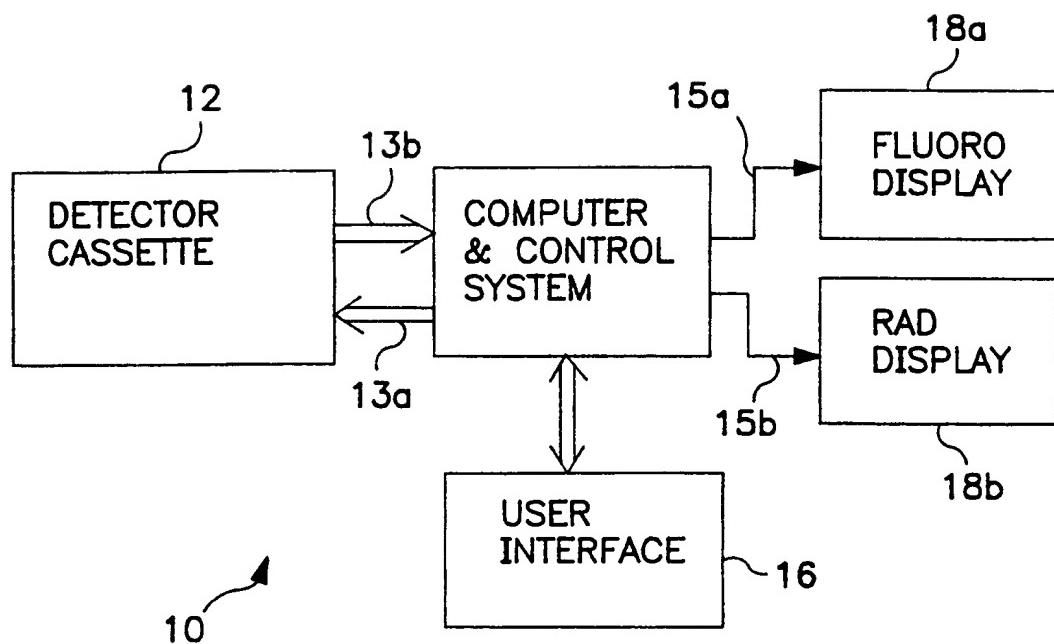
control signals.

FIG. 1
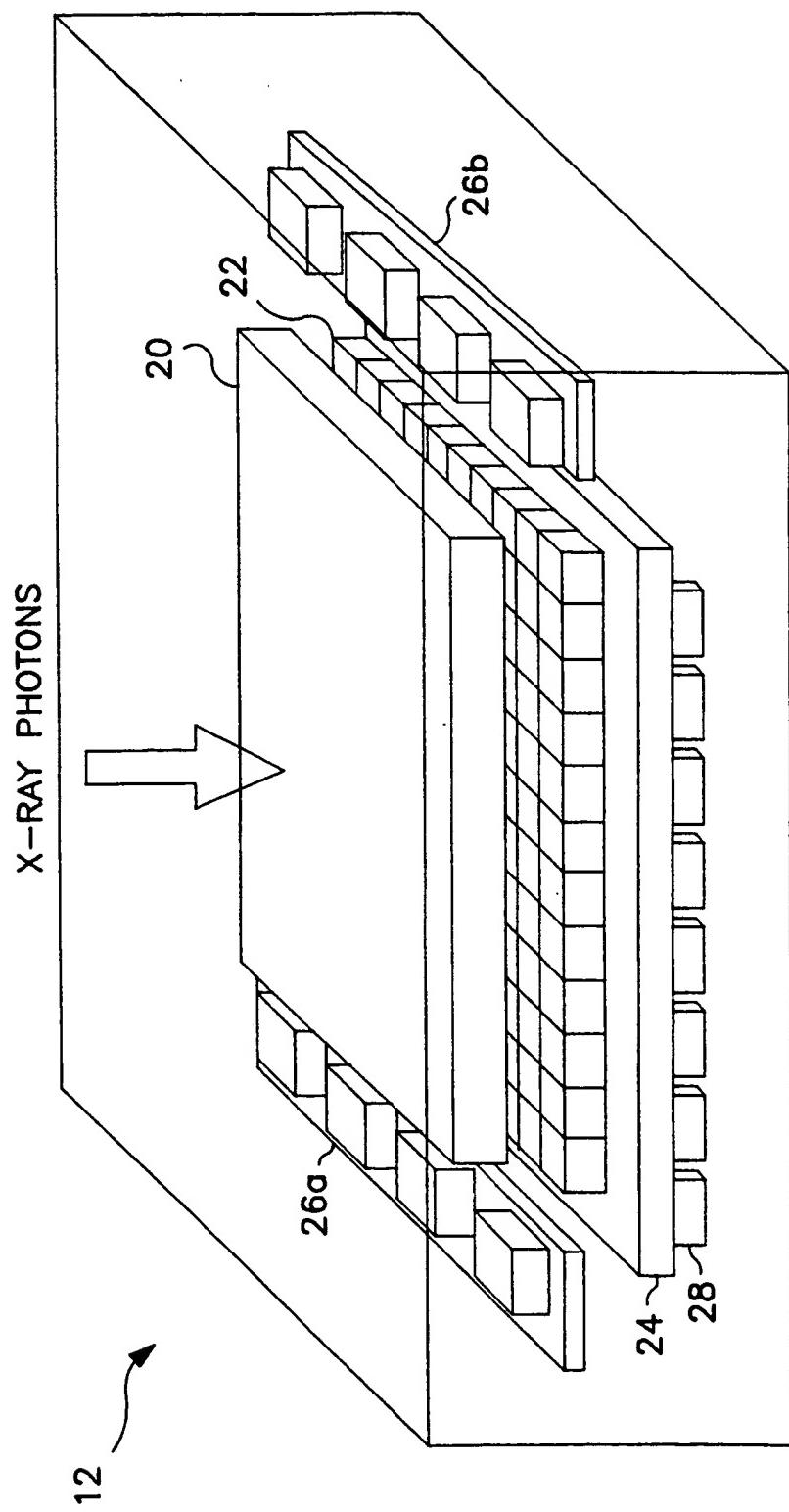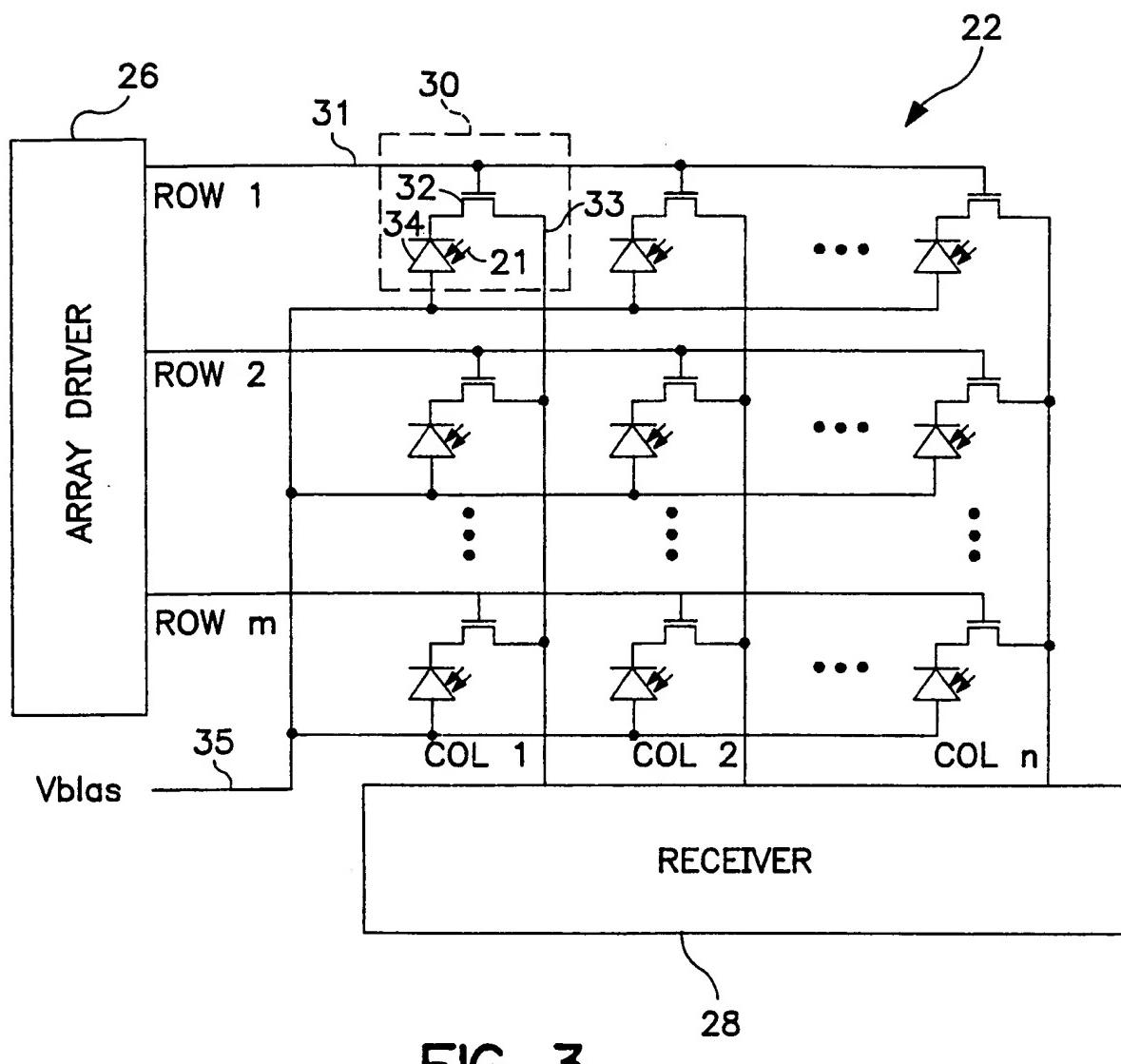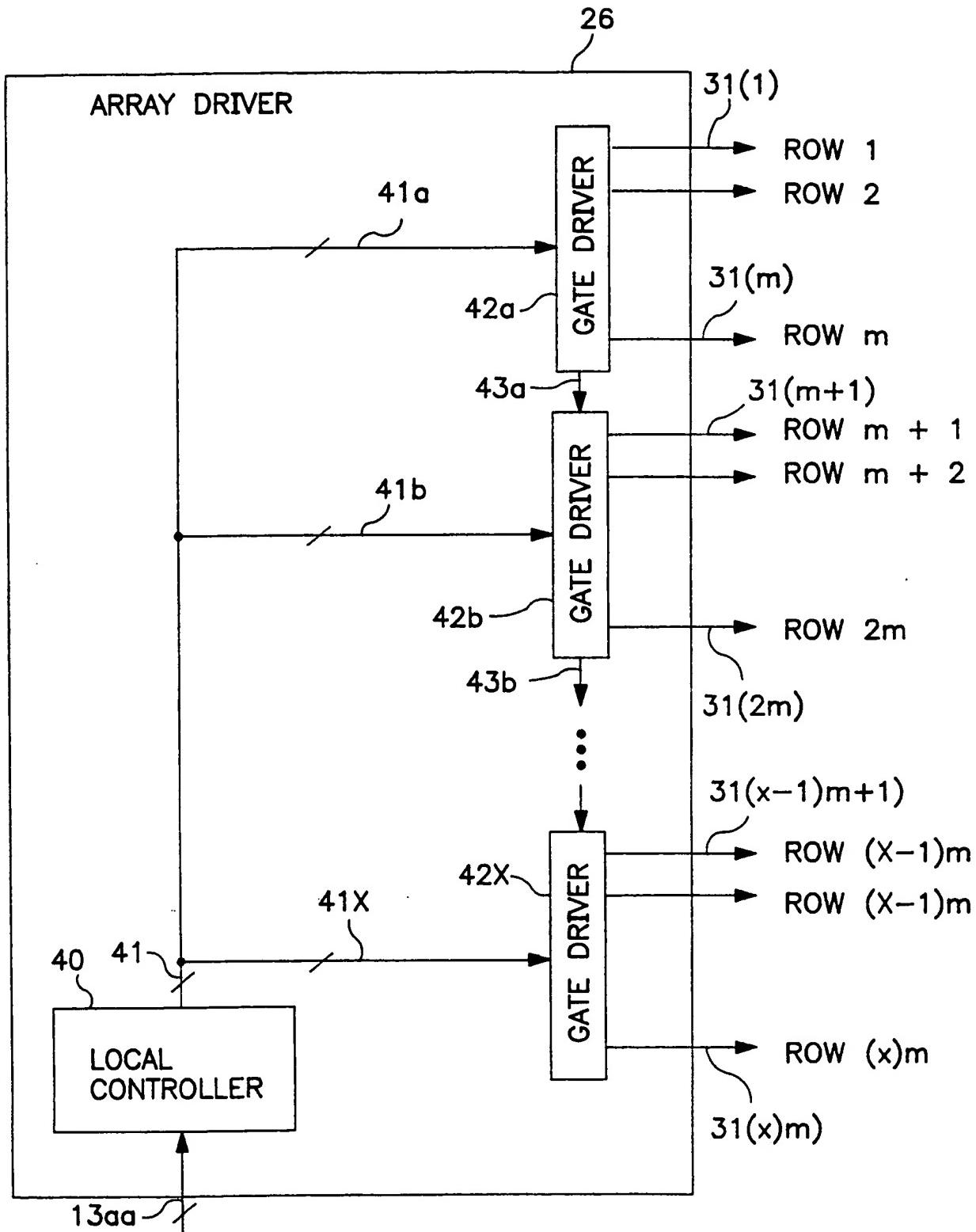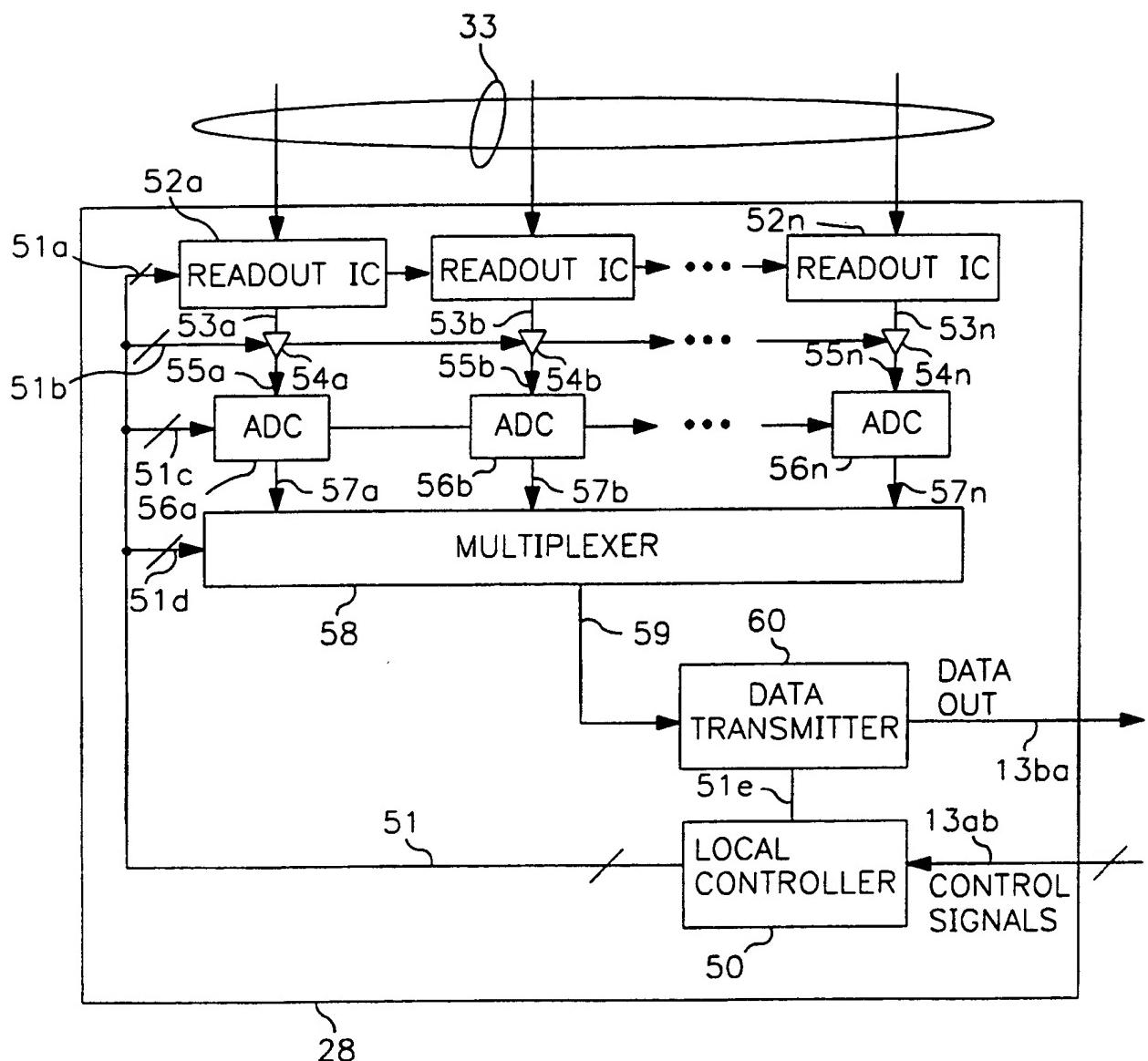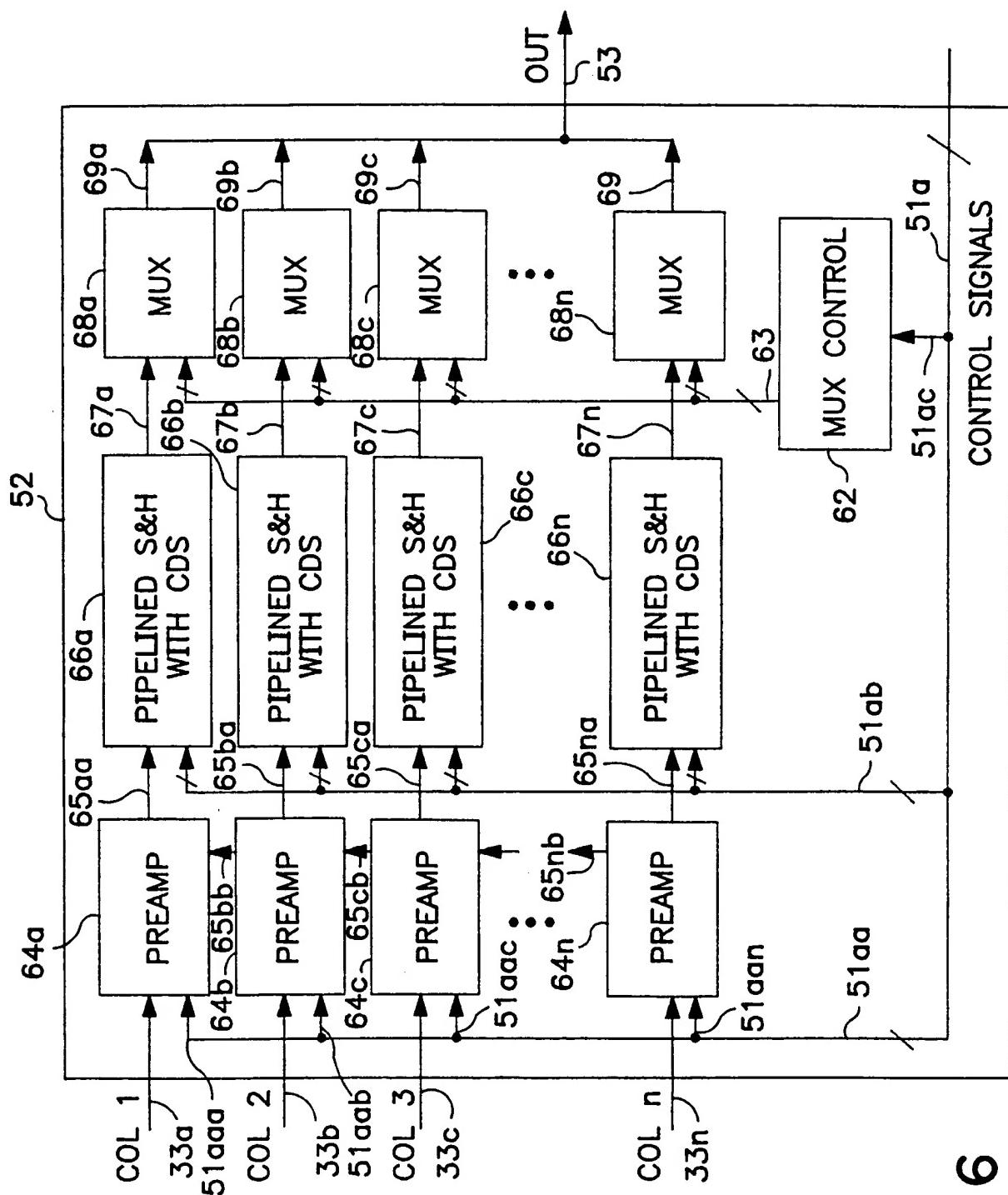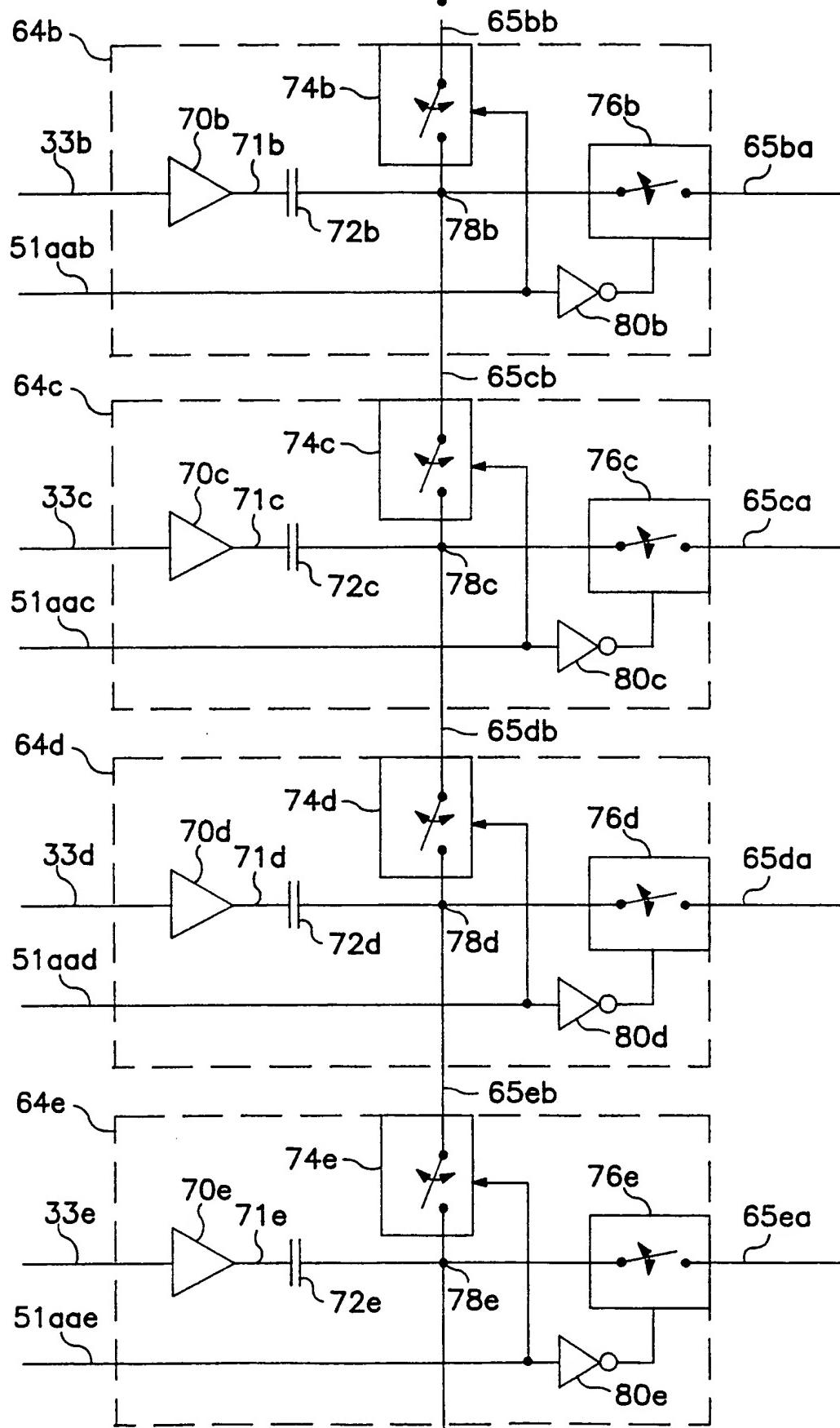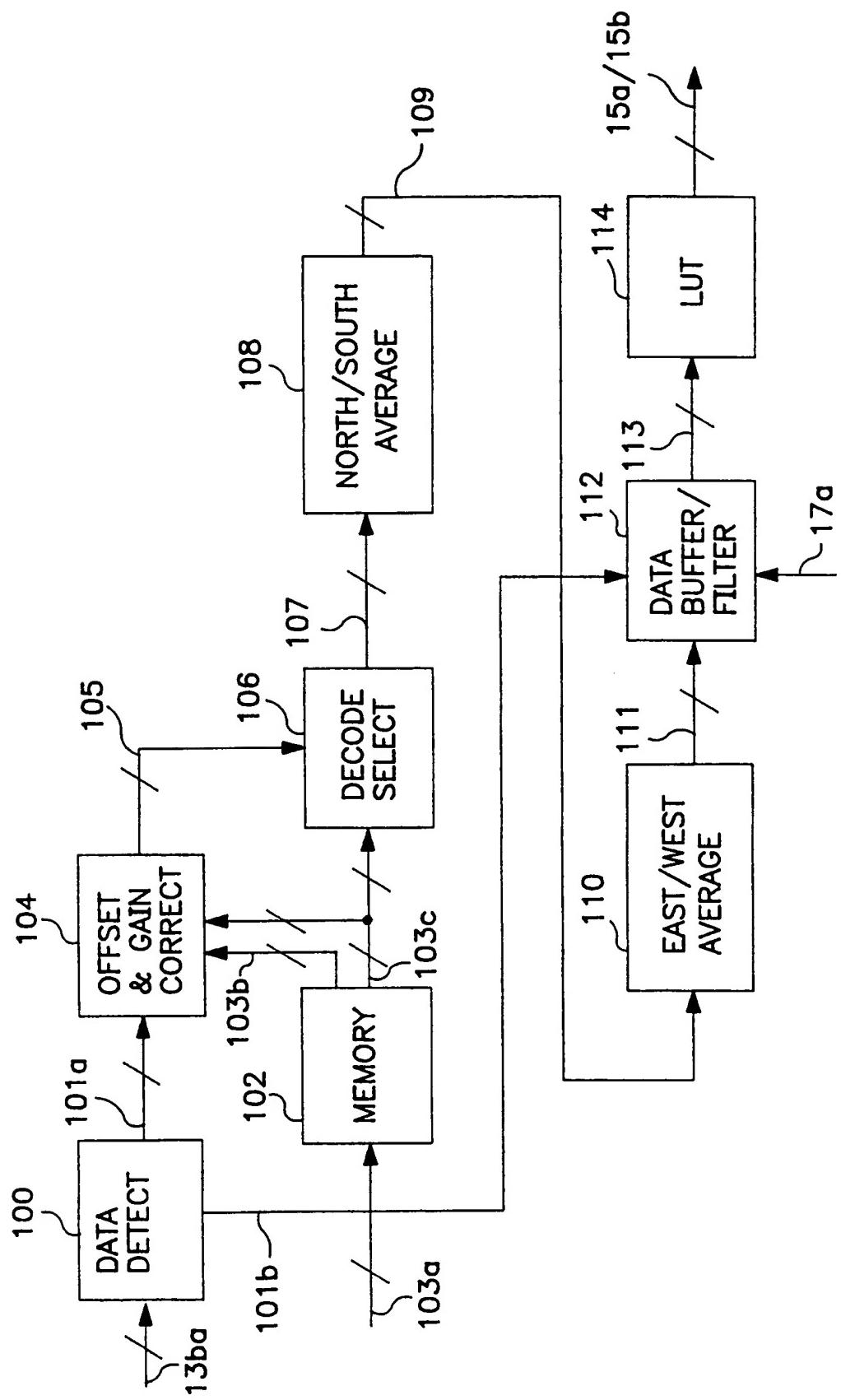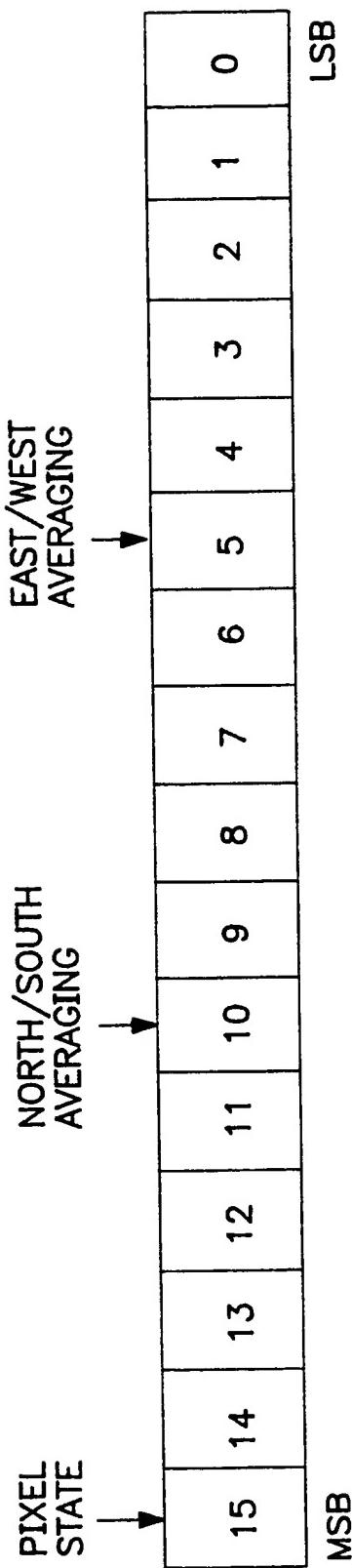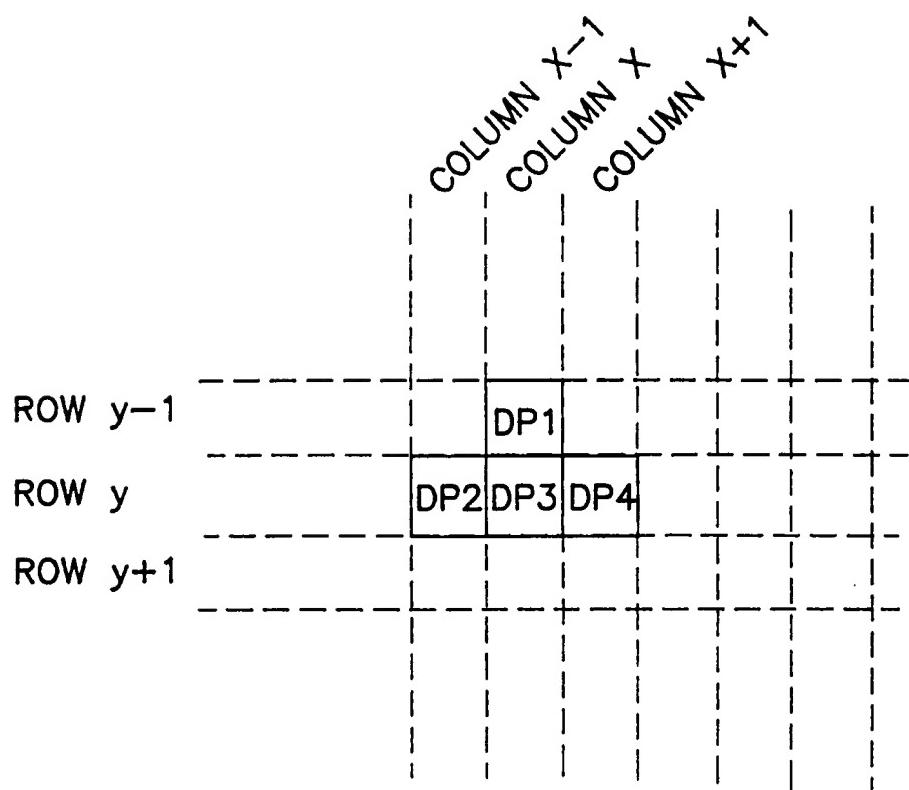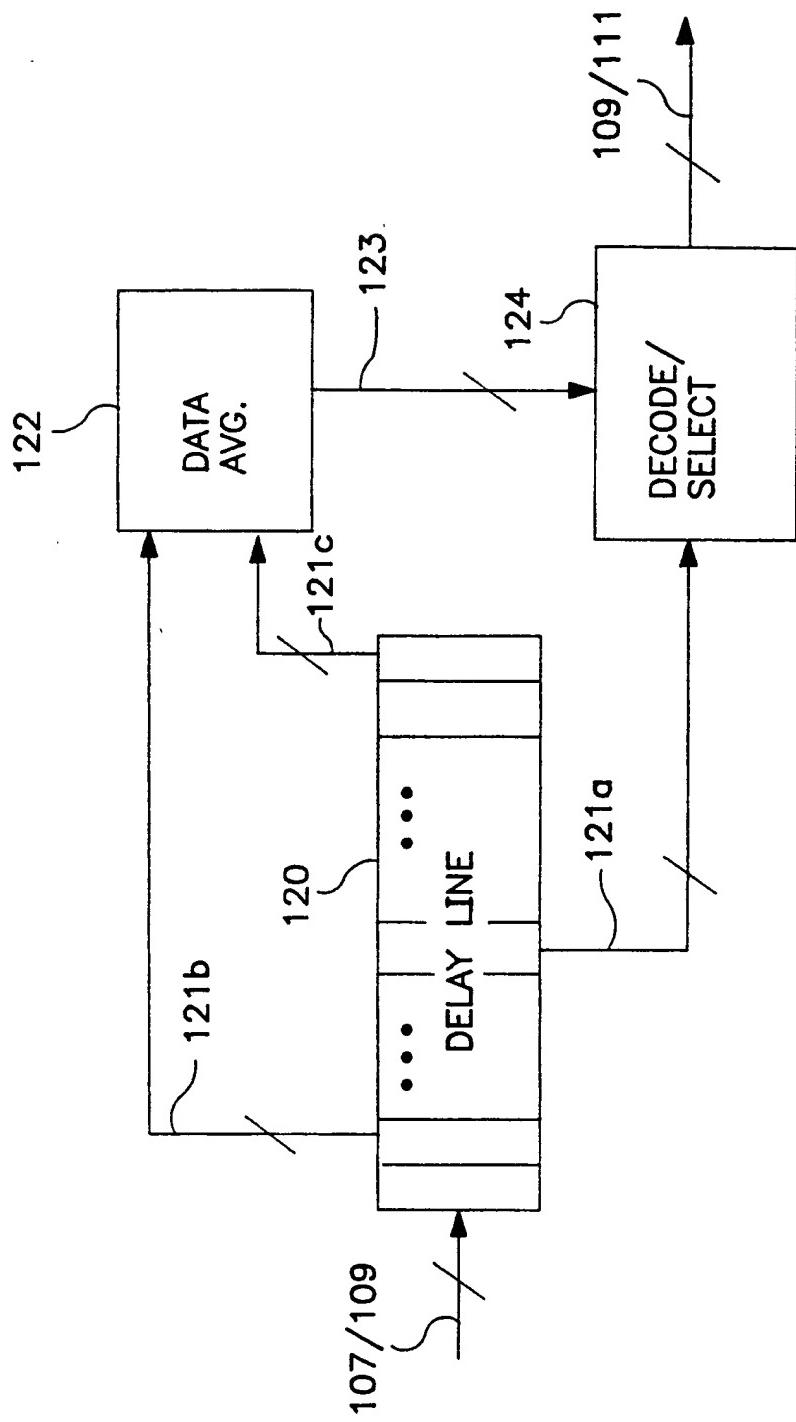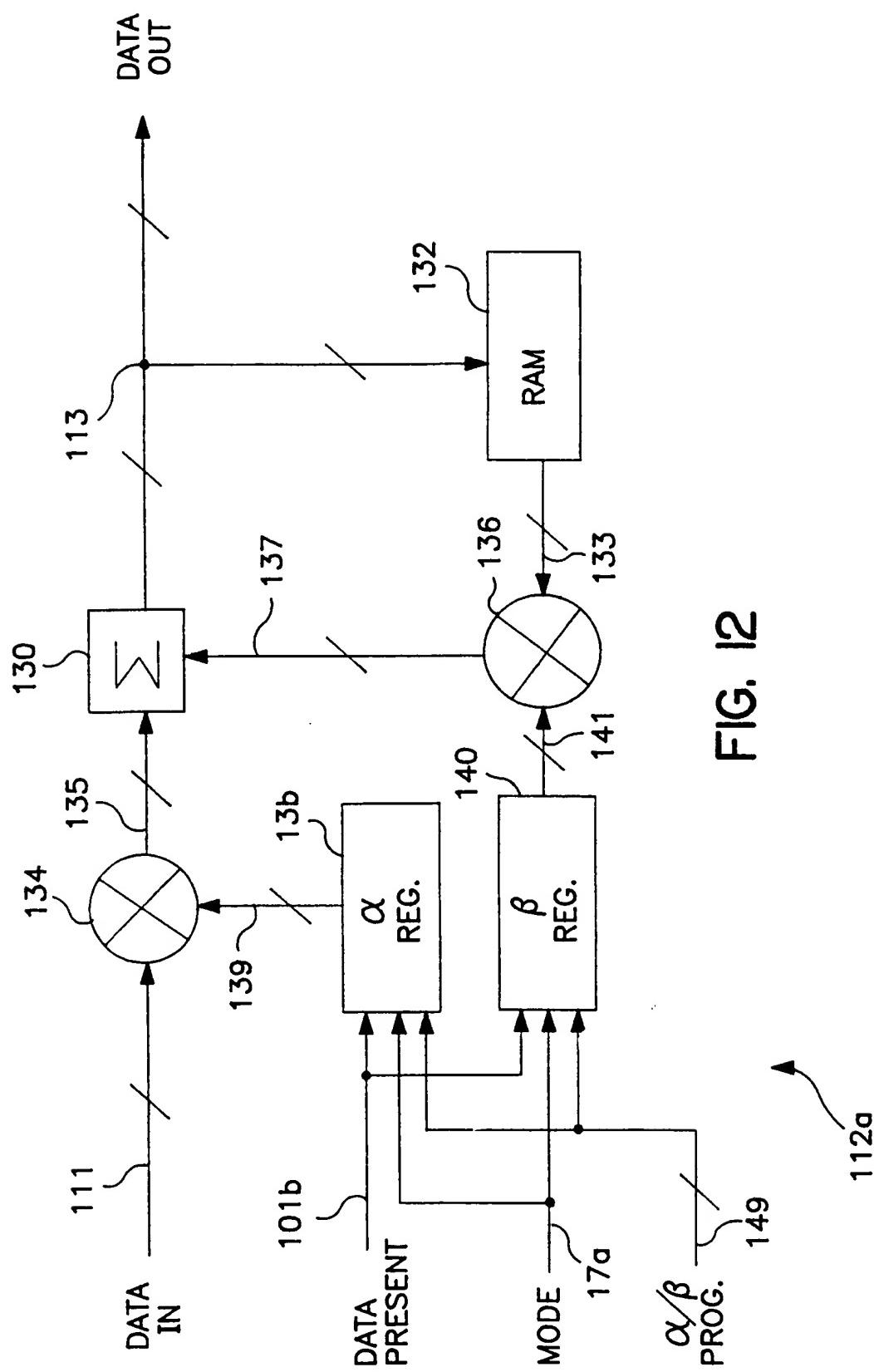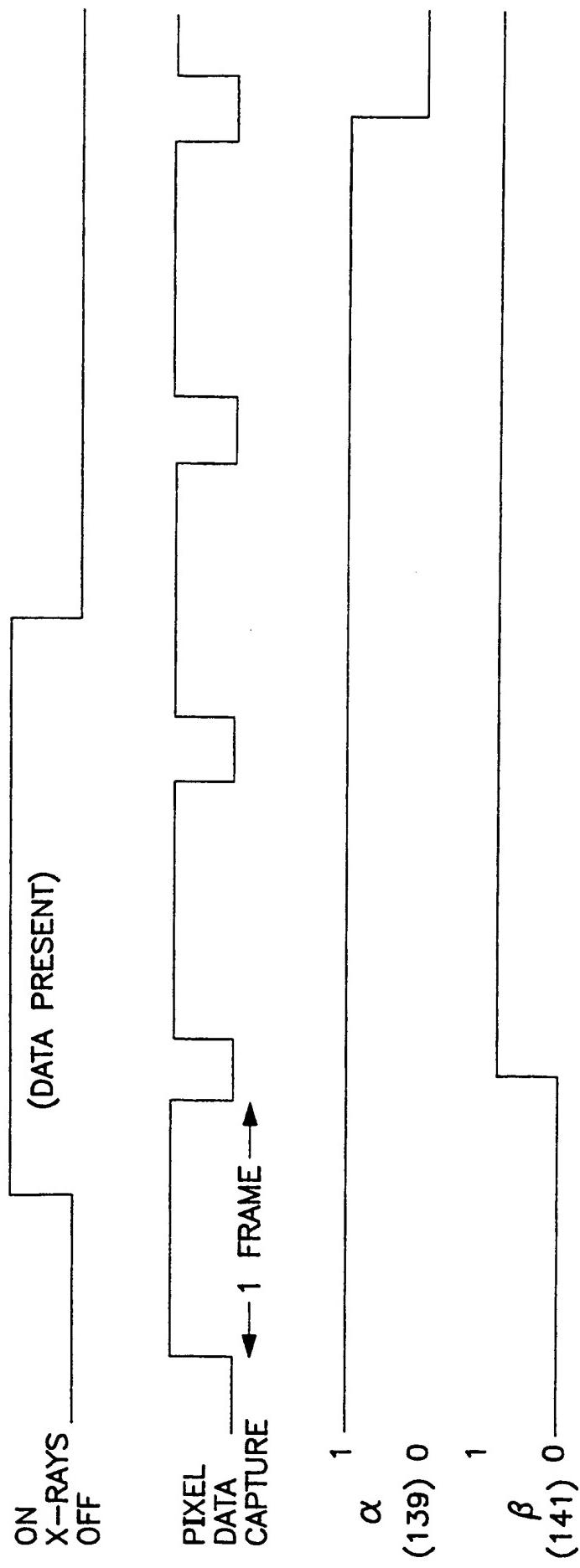
X-RAY PHOTONS

20
22
26b
26a
24
28
12

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIG. 8

PIXEL STATE →		NORTH/SOUTH AVERAGING →				EAST/WEST AVERAGING →									
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSB															LSB

103c

FIG. 9

COLUMN X−1
COLUMN X
COLUMN X+1

ROW y−1

DP1

ROW y

DP2 DP3 DP4

ROW y+1

FIG. 10

FIG. II

FIG. 12

FIG. 13
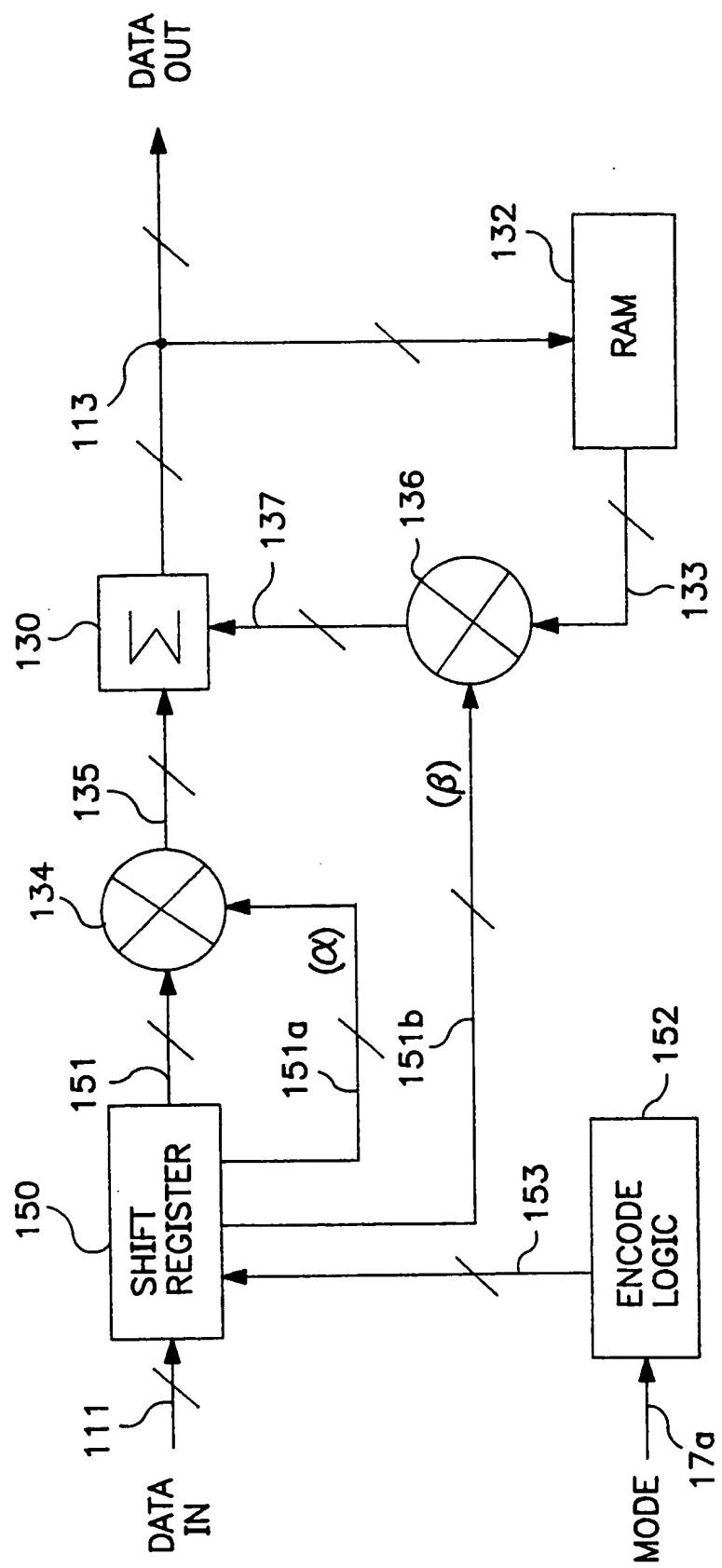
FIG. 14

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G06T5/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,Y	EP 0 776 124 A (PLANMED OY) 28 May 1997 see abstract see page 2, line 54 – page 3, line 16 see page 4, line 8 – line 15 see page 4, line 29 – line 34 see page 5, line 34 – line 39 see page 5, line 48 – line 51 ---	1-32
P,Y	US 5 657 400 A (GRANFORS PAUL R ET AL) 12 August 1997 see abstract see column 1, line 60 – column 2, line 11 see column 3, line 26 – line 29 see claim 1 -----	1-32

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 April 1998	15/04/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gonzalez Ordonez, O

Form PCT/ISA/210 (second sheet) (July 1992)

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0776124 A	28-05-97	FI 97665 B JP 9200625 A	15-10-96 31-07-97
US 5657400 A	12-08-97	NONE	